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GUIDELINES FOR THE ALIGNMENT SURVEY AND GEOMETRIC DESIGN OF HILL ROADS

(Third Revision)

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES/SKETCH

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GUIDELINES FOR THE ALIGNMENT SURVEY AND GEOMETRIC DESIGN OF HILL ROADS

1. INTRODUCTION

1.1 India is a vast country with diverse geological, climatic regions. Indian road network passes through different terrains including hills and mountains. Hilly regions consist of Himalayan region from North to North-East, the Central Highlands of Aravalli, Western and Eastern Ghats. The Himalayan region on its own covers about a fifth of the country's total area and about 3000 km of India's international borders. Hilly regions are generally deprived of Rail and Air connectivity with respect to plain terrain. Hence socio-economic development and strategic needs have resulted in lack of massive road construction programmes in hilly regions and such activities have increased many folds.

1.2 The Hill regions including the road networks are affected more frequently by floods due to torrential rainfall, landslides, snow avalanche etc. which compel many sections of road network closed during rainy season and winter season.

1.3 Design of hill roads need not be restricted to the absolute minimum values set out. Where conditions are favorable and the costs not excessive, use of more liberal values than the minimum should be preferred.

1.4 The recommendation about the Alignment Survey and Geometric Design of Hill Roads was first published in 1973 and revised in 1982 and 2001.

1.5 During the third meeting of Hill Roads and Tunnels Committee (H-10) held in Delhi on 24.05.2018, it was discussed that the IRC:52-2001 "The Alignment Survey and Geometric Design of Hill Roads" is dealing with the same chapters which are covered under IRC:SP:48-1998 "Hill Road Manual". Accordingly, the Committee decided to revise IRC:52 to incorporate the latest advancement in the field of alignment survey, equipment etc. and reference of the same would be given in IRC:SP:48 which is under revision. The draft was deliberated in various meetings of H-10 Committee and was finalized in its meeting held on 6th October, 2018 for placing before the Highways Specifications and Standards Committee (HSS). The revised draft was placed before the Highways Specifications and Standards Committee (HSS) in its meeting held on 23rd October, 2018. The HSS Committee approved the draft subject to the consideration of the observations of members. The Executive Committee in its meeting held on 27th October, 2018 approved the draft for placing before the Council of IRC. The Council in its 216th meeting held on 22nd November, 2018 at Nagpur (Maharashtra) considered and approved the same for printing.

The composition of H-10 Committee is given below:

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Kumar, Anil	....	Co-Convenor
Jaiswal, Vivek	....	Member-Secretary

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Director General (Road Development) & Special Secretary to Govt. of India	(Singh, B.N.), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

2. DEFINITIONS

2.1 **Steep Terrain** is a terrain where cross slope of the country is generally greater than 60 per cent.

2.2 **Mountainous Terrain** is a terrain with cross slope greater than 25 and 60 per cent.

2.3 **Rolling Terrain** is a terrain with cross slope greater than 10 and upto 25 per cent.

2.4 **Plain Terrain** is terrain where cross slope of the country is generally less than 10 per cent.

2.5 **Ruling Gradient** is a gradient, which in the normal course must never be exceeded in any part of the road.

2.6 **Limiting Gradient** is gradient steeper than the ruling gradient which may be used in restricted lengths where keeping within the ruling gradient is not feasible.

2.7 **Exceptional Gradient** is gradient steeper than the limiting gradient which may be used in short stretches only in extraordinary situations.

2.8 **Escape Gradient** is a reverse grade with a crash barrier provided at suitable location adjoining exceptional gradient for stopping of downhill vehicle in case of brake failure.

2.9 **Climbing Lane** is a lane provided as a separate additional lane for the uphill traffic for safe overtaking while negotiating the reach having continuous exceptional gradient.

2.10 **Hair-pin Bend** is a bend alignment resulting in reversal of direction of flow of traffic. A bend may be for reversing road direction on same face of hill slope.

2.11 **Lateral Clearance** is the distance between the extreme edge of the carriageway to the face of the nearest structure/obstruction.

2.12 **Ruling Minimum Radius of Curve** is the minimum radius of curvature of the centerline of a curve necessary to negotiate a curve at ruling minimum design speed.

2.13 **Absolute Minimum Radius of a Curve** is the minimum radius of the centerline of a curve necessary to negotiate a curve at absolute minimum design speed.

2.14 **Roadway Width** is the sum total of carriageway width and shoulder width on either side. It is exclusive of parapets and side drains.

2.15 **Road Lane Width** refers to the width of carriageway of the road in terms of traffic lanes. Single-lane 3.75 m, Intermediate-lane 5.50 m and double-lane 7.0 m (7.5 m with raised Krebs), multi-lane 3.5 m per additional lane.

2.16 **Sight Distance** is the distance along the road surface at which a driver has visibility of objects, (stationary or moving) at specified height, above the carriageway.

2.17 **Super-elevation** is the inward tilt or transverse inclination given to the section of a carriageway on a horizontal curve to reduce the effects of centrifugal force on a moving vehicle. Super-elevation is generally expressed as a slope.

2.18 **Transition Length** is the centerline length along a curve, radius of which goes on changing at a certain rate of change of acceleration.

2.19 **Vertical Clearance** is the height above the highest point of the travelling way i.e., the carriageway and part of the shoulders meant for vehicular use, to the lowest point of the overhead structure or rock surface.

2.20 **Benching** is the formation of a series of level platforms or ledges upon an incline.

2.21 **Berm** is the horizontal ledge or margin formed at the top or bottom of an earth slope.

2.22 **Passing Place** is an area provided on the side of the road at convenient locations to facilitate crossing of vehicles approaching from the opposite direction and toe to aside a disabled vehicle so that it does not obstruct traffic.

2.23 **Tunnel** is a passage through a hill to be used as a road.

3. SCOPE

3.1 The standard is relevant to new road as well as for improvements of existing roads. It is, however, not applicable to urban roads or city streets situated in hilly terrain.

3.2 The text deals with two main aspects of hill road construction, namely, alignment surveys for route selection and geometric design of the alignment. The first aspect, namely, the alignment survey including reconnaissance and preliminary surveys etc. are discussed. The various elements of geometric design are covered including brief planning criteria.

4. PLANNING CRITERIA

4.1 Classification of Hill Roads

4.1.1 As in the case of roads in plains, hill roads may be classified as one of the following :

(a) National Highways

(b) State Highways

(c) Major District Roads

(d) Other District Roads

(e) Village Roads

4.2 Planning of Roads in Hill Areas

4.2.1 Planning of road in hill areas is much different from that in plains. Significantly, large number of villages are sparsely populated and isolatedly located at different altitude unlike in plain areas. It is usually not possible topographically as well as economically to directly link them with motorable roads. Alignment of roads has, thus, to be circuitous and is primarily governed by topography and geological formation.

4.2.2 In hilly areas, road links should be provided on the basis of cluster or group of villages as far as feasible because the population of each village may be very low. Villages located within a radius 1.6 km and having altitude difference of not more than 200 m can be considered as one cluster or groups of villages. Isolated villages, having population more than 250 should be provided with an all-weather link road. For a cluster of villages of population less than 250, a selective approach of an all-weather road may be worked out keeping in view the local conditions.

4.2.3 For new roads, connecting new areas an assessment of traffic likely to be generated can be done by studies on population and consumer needs, development plans for the area and traffic on adjacent roads.

4.3 Ecological Consideration

4.3.1 Construction of roads in hilly region disturbs the ecosystem in many ways. The main ecological problems associated with hill roads construction are :

i) Geological disturbances

ii) Land degradation, soil erosion and landslides

iii) Destruction and denuding of forests
iv) Interruption and disturbance of drainage pattern
v) Loss of forestry and vegetation
vi) Aesthetic degradation
vii) Siltation of water-reservoirs

These factors underline the need to plan, align and construct hill roads after careful thought. The help of geologists and environmental specialists should, therefore, be enlisted while planning for hill roads. Hill Road Manual IRC:SP:48 may be referred for details in this regard.

In respect of environmental impact assessment, reference may be made to IRC:SP:19-2001 'Manual for Survey, Investigation and Preparation of Road Projects' and other IRC codes.

5. SURVEY AND ALIGNMENT OF HILL ROADS

5.1 General

5.1.1 In this section, guidelines for carrying out survey work to fix the alignment of hill roads situated primarily in a rural or non-urban area are given.

5.1.2 The requirement of the road is decided based on administrative, developmental, strategic, other needs and the obligatory points to be connected by the road. Control points between obligatory points are governed by saddles, passes, valleys, river crossings, vertical and over-hanging cliffs, forest and cultivated land and other natural features like escarpments, slide-prone, avalanche-prone and other unstable areas.

5.1.3 In order to explore the possibility of various alternative alignments, preliminary investigation shall start from the high obligatory or control summit points and proceed downwards. The alignment finally selected linking the obligatory and control points shall fit in well with the landscape. The aim shall be to establish a safe, easy, short and economically possible line of communication between the obligatory points considering the physical features of the region and traffic needs apart from least disturbance to the eco-system and the prevailing High Tension line, existing service lines. Ideal road alignment is the one which will cause the least over-all transportation cost including safety for road users taking into account the costs of construction, maintenance, and recurring cost of vehicle operation.

5.1.4 Introduction of hair-pin bends shall be avoided or minimized as far as possible. The bends shall be located on stable hill slopes, and their location in valleys avoided. Series of hair-pin bends on the same face of the hill shall be avoided.

5.1.5 Economy in operating cost of transport vehicles is achieved by adopting easy grades, minimizing rise and fall and by following a direct line as far as possible between obligatory points. Although shortest distance is an important factor, it may have to be sacrificed, at times, in order to obtain easy curvature and gradients, to avoid prohibitive cuts or fills and long river crossings and obstructions. Even a longer road length to ease gradient and curves may result in a more economical operating cost. Therefore economy in operating cost/road safety shall be the governing criteria in selecting the alignment of these roads.

5.2 Survey Methods and Sequence for Fixing of Alignment

5.2.1 With the guidelines enumerated under para 5.1, the activities, right from the initial survey to fixing final alignment of a hill road, shall follow sequence as under.

a) Reconnaissance of Routes
b) Determination of Centre line
c) Preliminary Survey of Routes
d) Choosing the possible alternative alignments from the surveyed routes
e) Ground verification and preliminary survey of the alternative alignments
f) Final detailed Location Survey for one of the selected alignments.

5.2.2 To facilitate the survey team in the tentative selection of alternative routes for subsequent detailed ground reconnaissance, the available topographical survey data shall be studied from the satellite or remote sensing data and topographical survey sheets.

5.3 Reconnaissance

5.3.1 General

Once the obligatory points are known, the next step will be to undertake reconnaissance survey in the following sequence:

a) Study of Satellite or remote sensing data along with topographical survey sheets, geological, meteorological, forest maps and aerial photographs, wherever available.

b) Preliminary reconnaissance and identification of possible routes connecting the obligatory points on the maps prepared based on Satellite or remote sensing data.

c) Fixing the possible routes based on longitudinal profile generated through satellite data, minimum distance, optimizing cutting and filling, availability of land (desired width), following basic factors of geometric design for desired speed, radius of curve, gradient.

d) Refinement of the alternative routes by correcting the aforesaid fixed routes by avoiding obstructions like minimum interference of forest area, habitant area but nearer to the habitant area, minimum crossing of Linear services like Railway lines, Canals, High Tension lines, Utilities network.

5.3.2 Reconnaissance with satellite data

Reconnaissance with Satellite/remote sensing data will provide a bird's eye view of the routes under consideration and the surrounding area. The alternative routes are marked on satellite data. These marked routes are to be corrected based on features on Topographical sheets which are available in the scale of 1 : 50000, i.e. 2 cm to 1 km, showing towns, villages, rivers and terrain features with altitudes and contour lines at intervals of 20 m. Close study of these sheets and the geological and meteorological maps of the area is essential in order to locate the obligatory and control points and to mark tentative alternative feasible routes on the topo sheet for further survey on ground.

5.3.3 Aerial reconnaissance

Further Aerial Reconnaissance to verify the topographic features and to verify the correctness of the details of obligatory/control points indicated in the topo sheets and also to find out other control points, if any, not shown in the map. Such reconnaissance will confirm the feasibility of the routes for proceeding further with ground reconnaissance.

5.3.3.1 Where required, this shall be done by Engineer in charge of the Project. This aerial reconnaissance is essential. The team doing the aerial reconnaissance will have to carry the following documents and equipment alongwith them:

a) Topographical sheets, where tentative routes are marked along with the details of obligatory and control points obtained on maps after processing of satellite data

b) Photo mosaics or aerial photographs of the area. if available, with pocket stereoscopes

c) Binoculars

d) Altimeters

e) Hand GPS demonstrating the coordinates

5.3.3.2 The reconnaissance party will travel the area covering the possible routes selected from study of maps and air photographs and examine the following points making notes of observations:

a) Correctness of obligatory points as given in the map

b) Correctness of control points as marked in the map

c) Existence of any other control points not marked in the map like

d) Major saddles/passes

e) River crossings

f) Slide/slip areas and sinking zones

g) Marshy areas

h) Camping sites

i) Rocky areas

j) Religious structure

k) High tension line and towers

l) Considerable thick and continuous habitation

m) Cross roads

n) Vegetation forest area and wild life area

o) Upcoming linear projects and hydro power projects

5.3.3.3 The coordinates of various obligatory and control points can also be recorded roughly from the Hand held GPS. On completion of the reconnaissance, the team shall do following:

a) Selection of various alternative feasible routes.

b) Decide on control points.

c) Identify the alternative route maps, if so needed, for taking up ground reconnaissance.

5.3.4 Ground reconnaissance

The various alternative routes found feasible as above are further verified physically in the field by ground reconnaissance to recommend the final route. It consists of general examination of the ground by walking or riding along the probable routes and collecting all essential and available data as per guidelines given in **Appendix-1**.

5.3.4.1 It will be advisable to associate a Geotechnical Engineer or Geologist with this work. Where necessary, local habitants shall also be associated with ground reconnaissance.

5.3.4.2 Traversing on the ground with hand GPS demonstrating the coordinates of the location shall be done during the ground verification. Points should be kept in mind that structures and utilities along the survey location should be noted along with the offset from the centre line of the survey alignment. This should cover all the necessary additional features along the identified routes. Best fit alignment route shall be selected in such a manner that would require minimum disturbance to structures and utilities with economical cost and maximum benefits with respect to socio economic concern of the survey alignment.

5.3.4.3 On the out set topographical survey ground control points should be installed at 250 m interval with help of Differential Global Positioning System (DGPS).

5.3.4.4 Ground penetrating radar technique needs to be adopted for mapping of under ground utility lines of water pipe lines

5.3.4.5 The general method of ground reconnaissance and fixing route/grade pegs by the reconnaissance team shall be as below:

(a) A starting point is fixed near the first obligatory point at a higher ground from the surrounding area from where one can see the next obligatory and/or some nearby control points. Being the starting point of the traverse survey, a cement concrete masonry block of dimensions 30 cm x 30 cm x 60 cm (deep) with upper surface 20 cm above the ground shall be erected on which the bench mark/ altitude, chainage, etc. shall be marked. From the altitudes of the two control points the approximate distance to be traversed between these two points can be ascertained taking into consideration a gradient flatter than the ruling gradient by 20 per cent or so (if ruling grade is 5%, grade assumed is 4%) depending on slope of the hill side. The jungle ahead of the fixed point is cleared along the route for placing and sighting the alignment and ranging poles. The width of jungle clearance shall be 0.6-1.2 m or even more if required. The direction of, route shall be checked.

(b) With abney level and/or ghat tracer the route line along the hill face shall be ranged at the required grade and the corresponding position on ground located by ranging rod and driving the grade peg into the ground, keeping the top of peg at level as per required gradient. Such grade pegs may be positioned at intervals between 25-100 meters or closer where required.

(c) The distance of the grade peg from the preceding one is measured and recorded in field book. On the peg, the serial number, distance, gradient (rise/fall) are marked in paint. The process is repeated at next location.

(d) The indication of the grade peg for the detailed survey party shall be marked by a clearly visible sign noticeable from a distance on the route. This is generally done by debarking a portion of a nearby tree of size 20 cm by 10 cm at the eye level and indicating in red paint direction, distance, the serial number and chainage of the connected grade peg. In places, where trees are not available, the hill face near the grade peg may be levelled about 30 cm square and then a pole at about 2 meter high with a cross piece tied to it is firmly fixed near the peg to indicate the position of the connected grade peg. In rocky area the level, line could be marked on the rock face with red paint and details required, as above, be written just above the level line. Any other method, depending upon the terrain and local facility available, may be adopted; the main aim being that the survey party for detailed survey, to be done later, shall not have any difficulty in locating the reference and grade pegs on the route. However. the method adopted shall be clearly indicated in the field book and reconnaissance report.

(e) Whenever a high hill range has to be crossed, it is essential to select a suitable pass or saddle (which becomes a control point) and to work from the top downwards. This is more convenient than working from bottom upwards, as in the latter case, there is a possibility of missing the pass or saddle especially when the area is dense jungle.

(f) Cross sections are taken with Abney level at about 25 to 100 meters apart or any other interval convenient to indicate the hill slope. Notes will have to be recorded in field book on the following points:

   (i) Nature and classification of soil (including rock out-crops, if any) encountered

   (ii) The character of waterways and streams

   (iii) Approximate span and type of culverts and bridging required

   (iv) Availability of materials such as timber, stone, gravel, sand, etc.

   (v) Location of quarries

   (vi) Possible camping places and availability of drinking water

   (vii) Any other useful information like availability of local labour, air dropping zone, helipad, etc.

(g) It has to be ensured that the survey and recording are made accurately by timely checking. A fortnightly progress report alongwith a diagrammatic chart showing the rough L-Section and also hill slopes (which need not be to scale) shall be prepared and submitted to the Engineer who ordered the survey. It shall contain adequate information to enable the Engineer to get a fairly good idea, not only on the progress of the ground reconnaissance. but also on the suitability of the proposed alignment.

5.3.5 Similar procedure for carrying out the preliminary ground reconnaissance and submission of report in A2 size shall be followed by the Survey Team in respect of all alternative routes also.

5.3.6 Reconnaissance report

On completion of reconnaissance survey on all the alternative routes, a report along with a comparative statement of the alternative routes in the proforma given at **Appendix-2** shall be prepared along with recommendations on the alignment to the Engineer. The report shall contain a plan on the scale of 1: 50,000, showing alternative alignments along with their general profile and rough cost estimate. A sample of topo-sheet, showing two alternative alignments proposed, is given in **Plate-1**. The Engineer of the area shall carry out inspection of the alternative alignments. Ground reconnaissance may disclose certain difficult stretches which call for detailed examination. A trace-cut might be made in such sections for inspection.

5.4 Preliminary Ground Survey

5.4.1 General

This survey consists of pegging at 20 or 25 m intervals the route previously selected on the basis of the reconnaissance survey more accurately and at regular and close intervals, cutting a trace 1.0 to 1.2 m wide and running an accurate traverse line along it by taking longitudinal and cross sections of the alignment establishing bench marks at convenient intervals and fixing reference pegs where the direction of the alignment changes. The data collected at this stage shall form the basis for the determination of the final centre line of the road. For this reason it is essential that every precaution is taken to maintain high degree of accuracy. Besides the above, general information concerning traffic, soil conditions, construction materials, drainage etc., relevant for fixing the design features shall also be collected during this phase.

5.4.2 This survey may be done in the following sequences:

a) Jungle clearance
b) Pegging the alignment
c) Trace cut
d) Survey
e) Map preparation

5.4.3 Jungle clearance

An advance party with required labourers and tools shall commence clearing the jungle along the selected alignment to provide clear sight distance for three or four ranging pole/levelling staff positions at a time on each direction of the alignment. The party shall commence work at least three days before the pegging party. The necessary clearance from forest department as required has to be obtained.

5.4.4 Pegging the alignments

A party consisting of the following personnel with necessary equipment shall commence checking grade level, directions and curvature of the alignment arrived at earlier, during the reconnaissance refixing the correct alignment and repegging the alignment at convenient and workable distance, two to three days after the jungle clearance has progressed:

Personnel

a) Junior Engineer	-1 No.
b) Overseer/Surveyor	-1 No.
c) Helper	-4 Nos.
d) Labour	-as required

Equipment

a) Total Station	-2 Nos.
b) Ghat tracer	-1 No.
d) Mettalic tape 30 m	-3 Nos.
e) T & P for labour	- as required
f) Prismatic Compass	-1 set
g) Binoculars	-2 pairs
h) Plain table survey equipment	-2 sets

5.4.5 The line, grade and direction of the selected alignment shall be properly checked and corrected with the Total Station with more details and accuracy. The gradient to be followed at this stage shall be easier than the proposed to be achieved on the road by a margin of 20 per cent or so as stated in para 5.3.4.5 (a). Procedure for pegging will be the same as in para 5.3.4.5 sub paras (c) and (d). However, the intervals of the pegs shall be 20 or 25 m as per ground and terrain condition. The size of the pegs may be 6 cm dia or square and 60 cm long out of which 45 cm be driven into the ground. The indication about the grade shall be provided at conspicuous locations so as to be easily visible from a distance as mentioned in para 5.3.4.5 sub paras (b) to (d).

5.4.6 Trace cut

A party consisting of the following personnel, shall carry cut the trace out along the selected alignment and follow the pegging party:

a) Junior Engineer	- 1 No.
b) Surveyor/Overseer	- 1 No.
c) Helper	- 2 Nos.
d) Labour with T&P	- as required

Trace Cut will be about 1.0 meter wide track cut along the selected alignment to facilitate access to the area for inspection and survey. It may not be possible to cut a trace where the pegged route traverses precipices and may, therefore, be detoured by cutting the trace either along the top or bottom periphery of these areas.

5.4.7 Machans

In continuous long stretches of rock, with sheer vertical faces where trace cutting is not possible, machans can be constructed by erecting framework with locally available-ballies, resting on suitable ledges or pegs driven in the crevices/cracks in the rock-face on the valley side. 0.75

to 1.0 m wide platform/decking of ballies/bamboos with suitable railing wherever required, is provided on the top of the framework. Where suitable ledge/support is not available, the machans are constructed by hanging cane suspenders from trees or pegs driven in crevices/cracks on the rock-face on hill side and the platform/decking is tied to these cane suspenders. Typical sketches of machans are shown in **Fig. 5.1**. Where the rock is steep and inaccessibly deep for construction of machans, temporary pathways can also be developed by driving jumpers of iron rods into the rock-face and putting wooden ballies or planks over them for the men to safely walk along.

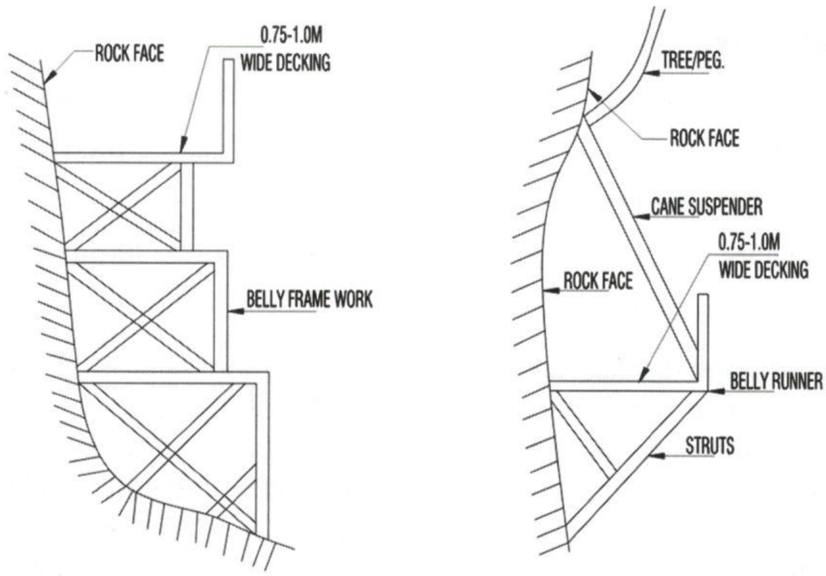


Fig. 5.1 Machans

The speed of construction of trace cut machans depends on the terrain and strength/skill of working party. For guidance and planning purpose, it may be assumed that a working party of about 50 – 100 labourers under a resourceful/imaginative supervisor/officer can achieve a daily progress of about 0.5 to 1.0 km of trace-cut in ordinary soil and 0.25 to 0.5 km in average rocky area, depending on cross slopes and jungle growth. The speed of construction of machans depends on availability of local materials like ballies/bamboos/cane, suitability of location for construction and skill of labourers. A gang of about 20 to 25 labourers can construct about 50 to 60 meters of machans per day in easy locations, whereas the speed can be as low as 10 to 15 meters per day in difficult locations.

Where ballies/bamboos are not easily available either because of non-availability or because of restrictions for their extraction, machans may be constructed using pre-fabricated angle iron section of 1.0 m to 1.5 m length which could be easily bolted at site.

5.4.8 Survey procedure

The survey shall cover a strip of sufficient width taking into account the degree and extent of cut fill, with some allowance for possible shift in the centre line of the alignment at the time of final design. Normally a strip width of about 30 m in straight or slightly curving reaches (i.e. 15 m on either side of centre line) and 60 m at sharp curves and hair-pin bends (i.e. 30 m on either side of centre line) shall meet the requirement.

Traverse along the trace cut shall be run with a Total Station. No hard and fast rule can be laid down as regards distance between two consecutive transit stations. In practice, the interval will be dictated by directional changes in the alignment, terrain condition and visibility. The transit stations shall be marked by means of stakes and numbered in sequence. These shall be protected and preserved till the final location survey.

Physical features such as buildings, monuments, burial ground, burning places, places of worship, pipelines, power/telephone lines, existing roads and railways lines, stream/river/canal crossings, cross drainage structures, etc. that are likely to affect the project proposals shall be captured by Total Station. Ground levels along the trace cut shall be taken at intervals of 20-25 m and at closer intervals whenever there are abrupt changes in slope and also establishing bench marks at intervals of 250 meters, exceptionally 500 meters, by running check levels on a closed traverse basis independently. It is particularly important that a single datum, preferably GTS datum, is used.

Cross sections shall be taken at intervals of 20 or 25 m and at points of appreciable change in soil conditions. While taking cross sections, soil classifications shall also be recorded. At sharp curves and difficult locations, detailed capturing of data shall be done for the plotting of contours. Interval of contours may be 2 m though this could be varied according to site conditions.

Now a days the survey is done with the help of D.G.P.S (Differential Global Positioning System) instrument & Total station which gives accuracy to ± 1mm.

Control points are established with the help of D.G.P.S instrument. For this purpose, a set of two pillars are generated along the road length. Usually size of pillar shall be 45x45x90 cm in M25 concrete with 60 cm embedded in the ground and 30 cm above the ground and metal plate at top. These points are prepared in such a way that are not likely to be disturbed during the construction activities. Normally these set of two pillars (spaced between 20 to 50 meters) are spaced about 4 to 5 kilometers with one set of pillars at the start of road project and one at the end of project. Each of these pillars have numbering and are associated with co-ordinate i.e. x, y & z. (i.e. Easting, Northing & elevation w.r.t. mean seal level). These x,y,z coordinates of these control pillars are determined accurately with help of DGPS instrument. The z values are transferred accurately from the nearest GTS level using the Auto levels.

Once the D.G.P.S control points are established then with the help of Total Station & prism. T.B.M (Temporary Bench Mark, normally spaced at an interval of 250 meters) are indentified and fixed on the ground which have separate No's & Co-ordinates (x, y & z) similarly other reference pillars can be generated so that each and every point coming in road alignment is assessable to at least two such points. The accuracy of survey can be checked when we start from one control D.G.P.S point and when another D.G.P.S. point is reached, their co-ordinates should tally because with two known points the location of any third point can be generated and so on the process is continued till a point is reached of known co-ordinates and if survey is correct then both their values of co-ordinates should tally. The coordinates of the temporary Benchmarks are fixed by carrying out traversing between the known control points

Then with help of total station, the contouring of the area is done by taking cross section at intervals of 5-10 m on curves and 20-25 m on straight line and the plan and profile of proposed road is prepared meeting the requirements of gradient, curvature and speed as per technical specifications.

5.5 Map Preparation

5.5.1 At the conclusion of the ground survey plan and longitudinal sections (tied to an accurate base line) are prepared for detailed study to determine the final centre line of the road. At critical locations like sharp curves, hair-pin bends, bridge crossings etc, the plan shall also show contours at 2 m intervals, so as to facilitate taking final decision.

5.5.2 Scales for the map shall generally be the same as adopted for the final drawings. Normally horizontal scale might be 1:1000 and the vertical scale 1:100. For study of difficult locations such as steep terrain, hair pin bends etc., it may become necessary to have plans to a larger scale.

It will be a good practice to do survey work in the forenoon and plotting work in the afternoon so that any doubts arising can be cleared immediately thereafter by ground verification.

5.6 Determination of Final Centre Line

5.6.1 Determination of final centre line of the road in the design office involves the following operations:

a) Detailed study shall be done of the plans, longitudinal profile, cross-sections and contours of the final alignment prepared during the ground survey to work out various alternatives for the centre line of the proposed road. Out of these, the best one satisfying the engineering, aesthetic, economic and environmental requirements shall be selected as the final Centre Line. Factors like economy in earth work, least disturbance to hill slope stability, efficient drainage, balanced cut and fill, requirement of protective works such as retaining/breast walls, etc. shall be kept in view while making the final choice.

b) For the selected final center line, a trial grade line is drawn taking into account the control points which are established by mountain passes, intersections with other roads, river crossings, unstable areas etc. In the case of improvements to an existing road, the existing levels are also kept in view.

c) For the centre line finally chosen, study of the horizontal alignment in conjunction with the profile is carried out and adjustments made in both, as necessary for achieving proper co-ordination.

d) Horizontal curves including spiral transitions are designed and the final centre line marked on the map. A typical example of Final Centre Line chosen is given in **Plate-2**.

e) The vertical curves are designed and the profiles are shown on the longitudinal sections.

5.6.2 The sub-group of this operation may comprise of the following personnel:

i) Assistant Executive Engineer/Assistant Engineer	- 1 No.
ii) Junior Engineer	- 1 No.
iii) Surveyor/Overseer	- 1 No.

iv) Helper - 4 Nos.

v) Labour - as required

5.7 Final Location Survey

5.7.1 General

The purpose of final location survey is to layout the final centerline of the road in the field based on the alignment selected in the design office and to collect necessary data for preparation of working drawings.

5.7.2 Transit survey

The Final Centre Line of the road, as determined in the design office, is translated on the ground by means of a continuous Total Station survey and pegging of the centre line on the ground as the survey proceeds. It will be necessary to fix reference marks, to be pegged along the final centre line for this purpose. These marks shall be generally 20 m apart in straight reaches and 10 m apart in curves. To fix the final centre line, reference pillars/control blocks of cement concrete of size 30 cm x 30 cm x 60 cm deep shall be firmly embedded in the ground. These shall be located beyond the expected edge of the cutting on the hill side. The maximum spacing of reference pillars may be 100 m. The following information shall be put down on the reference pillars:

a) Reduced distance of the reference pillar/block
b) Horizontal distance of the pillar/block from the centre line of the road
c) Reduced level at the top of the reference pillar
d) Formation level of the final centre line of the road.

The reference pillars shall be so located that these do not get disturbed during construction. Description and location of the reference pillars shall be noted in the field book for reproduction on the final alignment plans. Distance of the reference pillars from centre line of road shall be measured along the slope, the slope angle determined with Total Station, and the actual horizontal projection calculated.

The final centre line of the road shall be suitably pegged at 20 meters or closer intervals. The pegs are intended only for short period for taking levels of the ground along the centre line and the cross-sections with their reference. In the case of existing roads, paint marks may be used instead of pegs. Distance measurements along the final centre line shall be continuous, following the horizontal curves, wherever these occur. The sub-group for this operation may comprise of the following personnel:

a) Junior Engineer - 1 No.

b) Surveyor/Overseer - 1 No.

c) Helper - 2 Nos.

d) Labour - as required

5.7.3 Bench marks

To establish firm vertical control for location, design and construction, bench marks established during the preliminary survey shall be rechecked and where likely to be disturbed during construction, re-established at intervals of 250 meters (but not more than 500 meters), and at or near all drainage crossings.

5.7.4 Longitudinal sections and cross-sections

Levels along the final centre line shall be taken at all pegged stations and breaks in the ground. Cross-sections shall be taken at 20 m intervals. In addition, cross-sections shall be taken at points of beginning and end of spiral transition curves, at the beginning, middle and end of circular curves, and at other critical locations. All cross sections shall be with reference to the final centre line, extend normally up to the right-of-way limits and show levels at every 2-5 meter intervals and all breaks in the profile.

Centre line profile shall normally be continued at least 200 meters beyond the limit of the road project. This is intended to ensure proper connecting grades at both ends. With the same objective, profile along all intersecting roads shall also be measured up to a distance of about 150 meters. Further, at railway level crossings, the level of the top of the rails, and in the case of subways the level of the roof, shall be noted. On existing roads, level shall be taken at all points of intersection in order to help fix the final profile.

5.7.5 Proper protection of points of reference

5.7.5.1 A permanent bench mark in the shape of frustum of prism similar in the shape of forest pillars having size of 2.0 m x 2.0 m at base and 0.5 m x 0.5 m at top with height of 1.5 m shall be constructed with its identification as one of the km stone of the respective NH. Its properties w.r.t. coordinates shall be engraved. Its spacing can be kept as 90-100 km along the road network.

5.7.5.2 The final location survey is considered complete when all necessary data and information are available and ready for the designer to be able to plot the final profile and prepare the project drawings and detailed estimate. Among other things, field notes shall give a clear description and location of all the bench marks and reference points. This information shall be transferred to the plan drawings so that at the time of construction, the centre line and the bench marks could be located in the field without any difficulty.

At the time of execution, all construction lines will be set out and checked with reference to the final centre line established during the final location survey. It is important, therefore, that not only all the points referring the centre line are protected and preserved but these are so fixed at site that there is little possibility of their being disturbed or removed till the construction is completed. In the last stage of alignment survey, hydrological and soil investigations for the route should be carried out. These will enable details and protective works to be decide.

5.7.6 The survey and fixing of alignment having been done, the stage has been reached to design the road as per standards.

6. GEOMETRIC DESIGN

6.1 General

Hill roads have mostly to negotiate through difficult topography, inhospitable terrain and extremes of climatic conditions. As such, design of hill roads to predetermined standards, considering importance of safety and free flow of traffic, is necessary so that travel is safe and comfortable. Geometric design standards have been laid down keeping above in view.

6.1.1 Basic principles of geometric design

6.1.1 Design criteria of hilly terrain shall be applied where stretches of plain/rolling terrain are short and isolated. Similarly, the stretches where hilly terrain intervenes for short and/or isolated stretches in plain/rolling terrain, criteria for such stretches shall be as per standards for plain/rolling terrain.

6.1.2 A uniform application of design standards is desirable for safe and smooth flow of traffic. The use of optimum design standards will reduce the possibility of early obsolescence of the facilities likely to be brought about by inadequacy of the original standards.

6.1.3 As a general rule, geometric features of a highway except cross sectional elements do not lend to stage construction, particularly in the case of hill roads. Improvement of features like grade and curvature at a later date can be very expensive and sometimes be impossible. It is, therefore, necessary that ultimate geometric requirements of hill roads are kept in view right in the beginning.

6.1.4 Development of cross-section in stages is technically feasible. But this shall be decided only after very careful consideration, since hill roads need a lot of protective and drainage works like retaining walls, breast walls, drains of various types and categories etc, consistent with safety and sometimes the road may have to be altogether rebuilt when same is upgraded. If stage construction is unavoidable, better strategy will be to use dry masonry and/or crated masonry for drains, breast walls, pitching etc, locate the interceptor drain well back at the very start and provide culverts to full width formation/roadway to avoid the need for their widening subsequently. However, road being an important part or rather forerunner of all development activities, stage development will become inevitable over a period of time and as such a decision on this issue shall be based on needs for a period of 15-20 years or so.

6.1.5 The design standards indicated are absolute minimum. However, the minimum values shall be applied only where serious restrictions are placed by technical or economic considerations. General effort shall be to exceed the minimum values on safer side to the extent possible. Where the minimum design standards cannot be adopted for inescapable reasons, proper signs shall be put sufficiently in advance to inform the road users. The intention shall be to provide a road to the user with such geometrics which gives safe and reasonably comfortable travel.

6.1.6 The standards have been classified separately for mountainous and steep terrain. Generally, the standards for steep terrain take lower values of design speed, radii of curve etc.

It is likely that in many sectors, the terrain change from mountainous to steep or vice versa may be within short distances. It is, however, not the intention to change standards frequently. In practice, stretches shall be classified as mountainous or steep depending on pre-dominant terrain in the stretch and accordingly standards adopted for that stretch. The same standards shall, generally, continue for maximum distance possible/practicable. Elements of a Roadway (in hills and plains), classification of terrain and Road-land widths are depicted in **Figs. 6.1, 6.2** & **6.3** respectively.

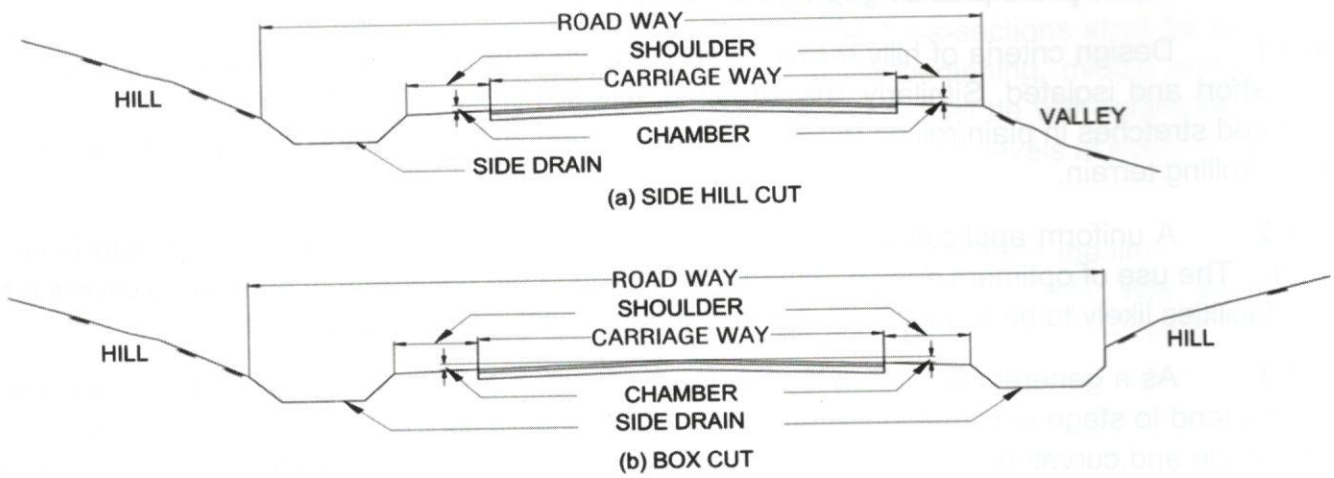


Fig. 6.1 Elements of Roadway

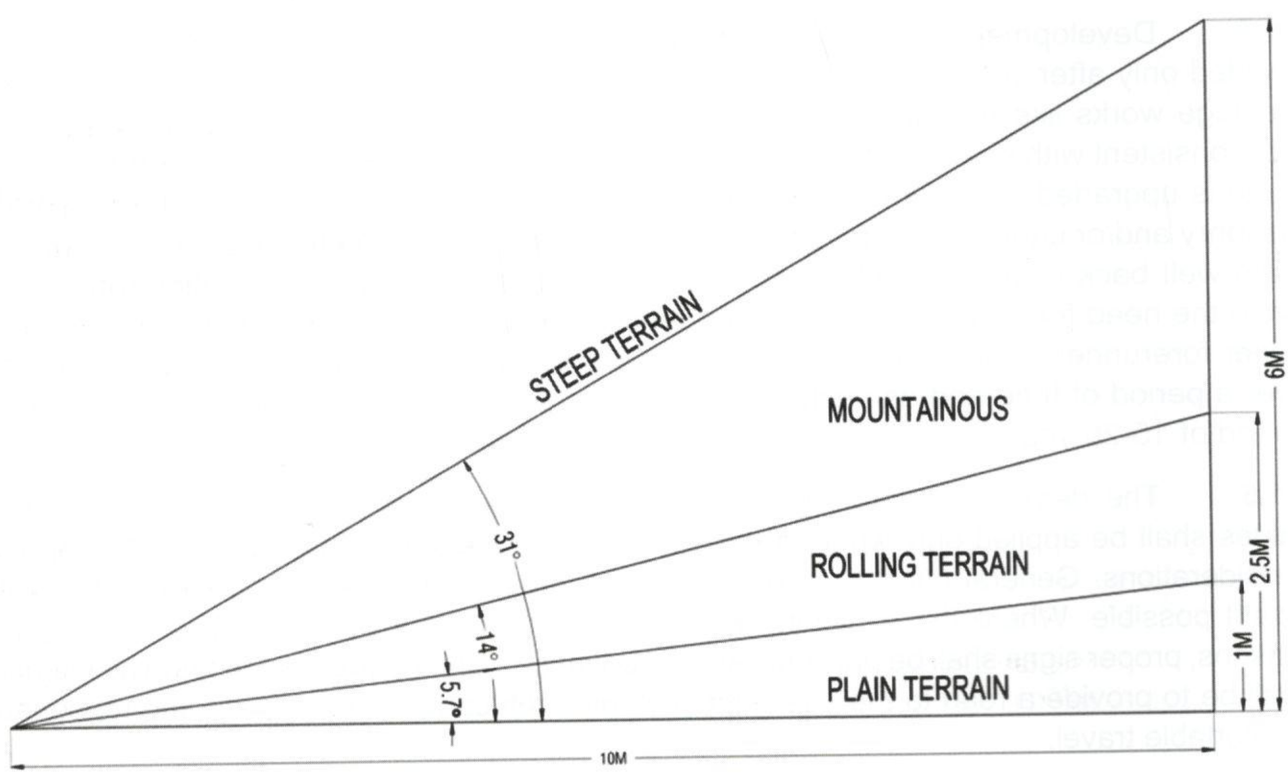


Fig. 6.2 Classification of Terrain

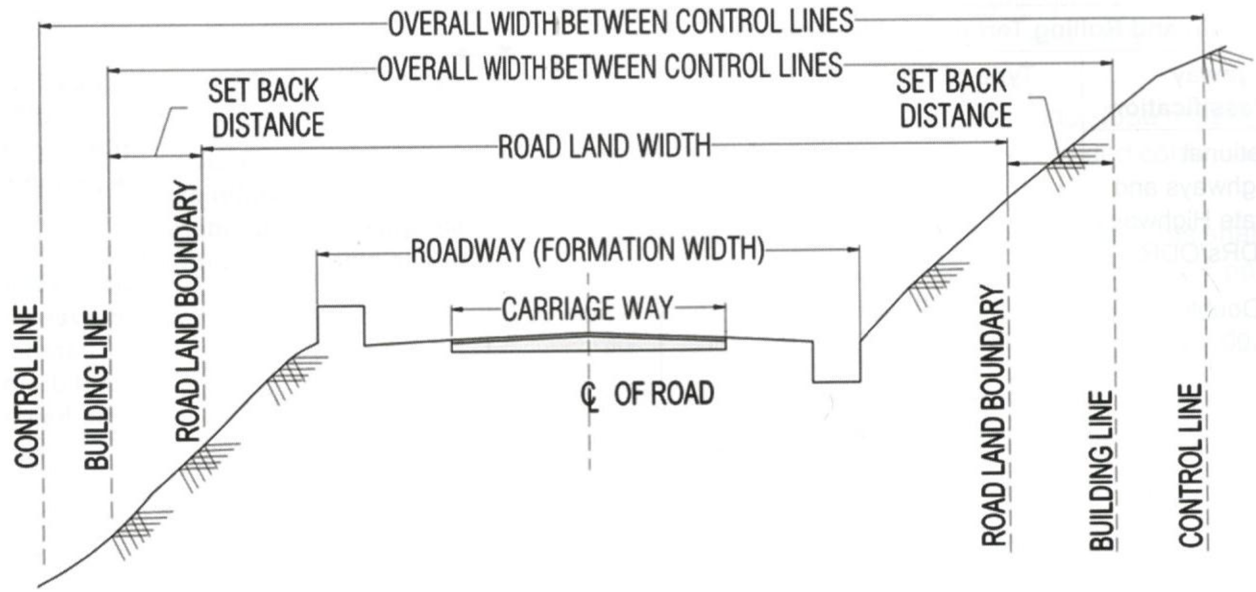


Fig. 6.3 Road Land

6.2 Width of Road Land, Roadway, Carriageway and Shoulders

6.2.1 Desirable widths of road land (right of way) for various categories of roads are given in **Table 6.1** (Hilly Areas of Mountainous and Sleep Terrain)

Table 6.1 Desirable Road Land Widths (m)

S. No.	Road Classification	Open Areas		Built-up Area	
		Normal	Exceptional	Normal	Exceptional
1	National and State Highways (Double Lane)	24	18	20	18
2	Major District Roads	18	15	15	12
3	Other District Roads	15	12	12	9
4	Village roads	9	9	9	9

Notes: 1. In order to ensure proper sight distance, It may be necessary to acquire additional right of way over that indicated in the Table. Right of way shall be enough to ensure minimum set back of 5 m for building line from edge of road land boundary.

2. Additional land is required at locations involving deep cuts, high fills and unstable/landslide areas need to be protected for overall stability.

3. If the road is planned to be upgraded in the future, land width shall correspond to higher class of road.

6.2.2 Width of carriageway, shoulders and roadway for various categories of roads are given in **Table 6.2**.

Table 6.2 Widths of Carriageway, Shoulder and Roadway

<table>
<tr><td colspan="8">In Plain and Rolling Terrain of Hilly Area</td></tr>
<tr><td>Highway Classification</td><td colspan="2" rowspan="2">Type of Section</td><td colspan="4">Shoulder Width (m)</td><td rowspan="2">Roadway Width (Carriageway + Shoulders) excluding extra width on horizontal curves, side parapet and drain & median (m)</td></tr>
<tr><td rowspan="5">National Highways and State Highways MDRs/ODRs

i. Double Lane (7.00 m)</td><td>Paved (m)</td><td>Earthen (m)</td><td>Total width of shoulders on one side (m)</td><td>Total width of shoulders on both sides (m)</td></tr>
<tr><td colspan="2">Open country with isolated built up area</td><td>2.5</td><td>1.5</td><td>4.0</td><td>8.00</td><td>15.00</td></tr>
<tr><td colspan="2">Built up area (2-lane section)</td><td>2.5</td><td>-</td><td>2.5</td><td>5.00</td><td>12.00</td></tr>
<tr><td colspan="2">Approaches to grade separated structures</td><td>2.5</td><td>-</td><td>2.5</td><td>5.00</td><td>12.00</td></tr>
<tr><td colspan="2">Approaches to bridges/culverts</td><td>2.5</td><td>1.5</td><td>4.0</td><td>8.00</td><td>15.00</td></tr>
<tr><td colspan="8">In Mountainous and Steep Terrain (in Hilly Area)</td></tr>
<tr><td rowspan="4">National Highways and State Highways MDRs/ODRs

i. Double Lane (7.00 m)</td><td rowspan="2">Open country with isolated built up area</td><td>Hill Side</td><td>1.5 m</td><td>-</td><td>1.5 m</td><td rowspan="2">4.00 m</td><td rowspan="2">11.00</td></tr>
<tr><td>Valley Side</td><td>1.5 m</td><td>1.00 m</td><td>2.50 m</td></tr>
<tr><td rowspan="2">Built up area and approaches to grade separated structures bridges</td><td>Hill Side</td><td>0.25 m + 1.5 m (Raised)</td><td>-</td><td>1.75 m</td><td rowspan="2">3.5 m</td><td rowspan="2">10.50</td></tr>
<tr><td>Valley Side</td><td>0.25 m + 1.5 m (Raised)</td><td>-</td><td>1.75 m</td></tr>
</table>

Notes:

1. Width of paved shoulders in approaches to grade separated structures shall extend on either side of the structures in entire length of retaining/RE wall. The retaining/RE wall on either side shall be abutting the paved shoulders and shall have crash barriers on top.
2. In case retaining wall with parapet is provided on valley side, the earthen shoulder may not be provided.
3. On horizontal curve roadway width shall be increased to provide for extra widening of curve.
4. Where embankment is more than 6 m high kerb with channel shall be provided at the end of paved shoulder to channelize the drainage as an erosion control device in accordance with section 6 of IRC:SP:73-2018 and earthen shoulder shall be raised upto the level of kerb.
5. The roadway widths are exclusive of parapets (usual width 0.6 m) and side drains (usual width 0.6 m) and divider medians (usual width 2.00/1.20 meter). Formation width shall include width to accommodate carriage way divider/median (wherever required) + shoulders + parapet on valley side + drain on hill side + extra width on horizontal curves (wherever required).

6. On roads subject to heavy snow fall, where snow clearance is done over long periods, roadway width may be increased by 1.5 m. However, the requirement of such widening may be examined with reference to ground conditions in each case considering terrain traffic and other influencing conditions and factors.
7. In hard rock stretches or unstable locations where excessive cutting may lead to slope failure, the width may be reduced by 0.8 m on two lane. Where such stretches are to be provided continuously for long distances, passing places shall be provided.
8. Strategic and border roads for military/paramilitary/security forces operations/movements shall be constructed for not less than two lane carriageway alongwith paved shoulder on hill side + paved and earthen shoulder on valley side on same lines of national highway.
9. Wherever, divider/median is required to be provided for the cases of divided highway of all category roads, the minimum 1.20 meter wide divider/median shall be provided.

6.2.3 The clear roadway width on culverts and causeways (measured from inside to inside of parapet walls or kerbs).

6.2.4 For bridges, the clear width minimum between kerbs shall be 7.5 m for double lane bridges.

6.2.5 In case of widening of the existing two-lane road to four-lanes, it would be desirable to plan a separate alignment for the additional two-lanes/split highways, in order to avoid the problems of stability of the existing hill slopes.

6.3 Capacity Considerations in Hill Roads

6.3.1 IRC:64 "Guidelines for Capacity of Roads in Rural Areas" contains recommended design service volumes for hill roads also. These are given in **Table 6.3**.

6.3.2 The capacity of two-lane roads can be increased by providing paved and surfaced shoulders at least 1.5 m width on either side. Provision of hard paved shoulders results in slow moving traffic being able to travel on the shoulder which reduces the interference to fast traffic on the main carriageway. Under these circumstances, 15 per cent increase in capacity can be expected, vis-à-vis, the values given in **Table 6.3**.

Table 6.3 Recommended Design Service Volumes for Hill Roads

S. No.	Types of Road	Design Service Volume in PCU/day		
		Carriageway Width	For low curvature (0-200 degrees per km)	For high curvature (above 200 degrees per km)
1.	Single-Lane	3.75 m	1,600	1,400
2.	Intermediate-Lane	5.50 m	5,200	4,500
3.	Two-Lane	7.0 m	7,000	5,000

Remark : Generally up-gradation of Single Lane to Intermediate Lane or construction of new Intermediate Lane needs to be discouraged.

6.4 Camber/Cross Fall

6.4.1 Generally, the pavement in straight reaches shall be provided with a crown in the middle and surface on either side sloping towards the edge. In case of winding alignments where

straight sections are few and far between, a uni-directional cross fall towards the hill side may be given having regard to factors such as the direction of super-elevation at the flanking horizontal curve, easy drainage and problem of erosion of downhill' face etc. Typical section of road with camber and cross-fall is given in **Fig. 6.4**.

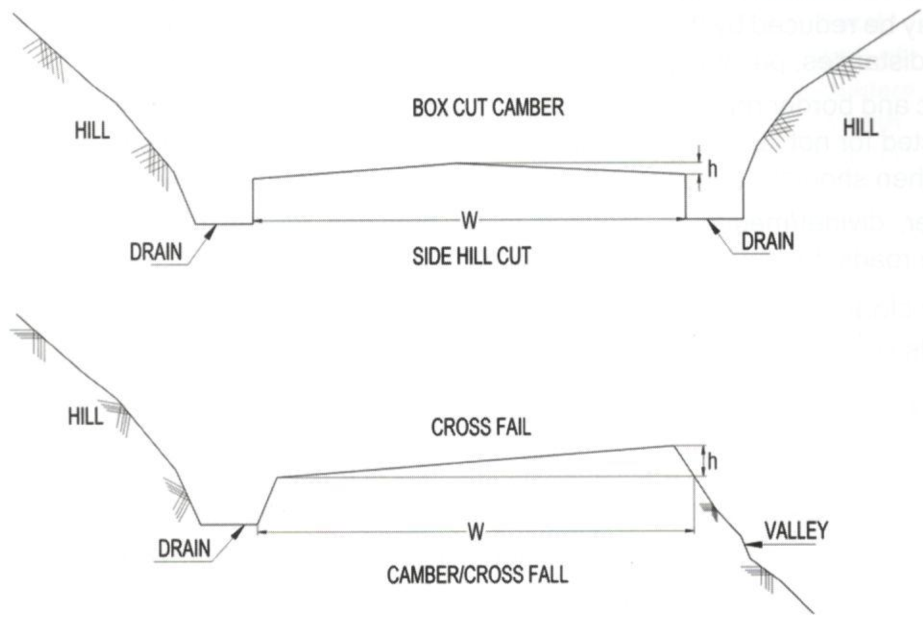


Fig. 6.4 Camber/Cross Fall

6.4.2 Camber/cross fall on straight section shall be as follows:

a. Earth road	-	3 to 4 per cent	(1 in 33 to 1 in 25)
b. Gravel or WBM surface	-	2.5 to 3 per cent	(1 in 40 to 1 in 33)
c. Thin bituminous surfacing	-	2.0 to 2.5 per cent	(1 in 50 to 1 in 40)
d. High type bituminous surfacing	-	1.7 to 2.0 per cent	(1 in 60 to 1 in 50)

6.4.3 For a given type of surface steeper values shall be adopted for high intensity rainfall area and lower values for low intensity rainfall area.

6.4.4 Cross fall for earth shoulders shall be atleast 0.5 per cent more than the pavement camber subject to a minimum of 3 per cent. If the shoulders are paved, cross fall appropriate to the type of paved surface as given in para 6.8.2 shall be provided. On super elevated sections the earth portion of the shoulder on the outer side of the curve shall be provided with a reverse cross fall of 0.5% so that the earth does not drain on the carriage way and storm water drains out with minimum travel path.

6.4.5 As the provision of cross-fall and super elevation tend to oppose each other in re-entrants and drainage gets affected, appropriate transition and drainage arrangements shall be made.

6.5 Design Speed

6.5.1 The design speeds for various categories of hill roads are given in **Table 6.4**

Table 6.4 Design Speed (km/h)

S. No.	Road Classification	Mountainous Terrain		Steep Terrain	
		Ruling	Min	Ruling	Min
1	National and State Highways	50	40	40	30
2	Major District Roads	40	30	30	20
3	Other District Roads	30	25	25	20
4	Village Roads	25	20	25	20

6.5.2 Normally, ruling design speed shall be the guiding criteria for correlating the various geometric standards. Minimum design speed may, however, be adopted in sections where site conditions including costs do not permit adoption of ruling design speed.

6.6 Sight Distance

6.6.1 Visibility is an important requirement for safety on roads. For this, it is necessary that sight distance of sufficient length is available to permit drivers enough time and distance to control their vehicles to avoid accident.

6.6.2 Two types of sight distances are considered in design of hill roads. Provision of overtaking sight distance is, by and large, not feasible on hill roads and, therefore, this category of sight distance is not discussed further. However, vision berms may be provided by benching on hill sides, in curves to provide better sighting of vehicles wherever felt necessary. The height of bench may be 1.2 m from the crown of the carriageway. These are:

a) Stopping sight distance which is the clear distance ahead needed by a driver to bring his vehicle to a stop before meeting a stationary object in his path. It is the sum of braking distance at the particular speed plus the distance travelled by the vehicle during perception and brake reaction time.

b) Intermediate sight distance is defined as twice the stopping sight distance.

6.6.3 Design values of both sight distances and criteria for measurement of sight distance are given in **Tables 6.5** and **6.6** below :

Table 6.5 Design Values of Stopping and Intermediate Sight Distance for Various Speeds

Speed (km/h)	Design values – meters	
	Stopping Sight Distance	Intermediate Sight Distance
20	20	40
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120

Table 6.6 Criteria for Measuring Sight Distance

S. No.	Sight Distance	Driver's eye height	Height of object
1	Safe stopping distance	1.2 m	0.15 m
2	Intermediate sight distance	1.2 m	1.2 m

6.6.4 On hill roads, stopping sight distance is absolute minimum from safety angle and must be ensured regardless of any other considerations. It would be a good practice if this value can be exceeded and visibility corresponding to intermediate sight distance provided in as much length of road as possible. Advantage of intermediate sight distance is that the driver is able to get reasonable opportunities to overtake with caution and driving task becomes much easier.

6.6.5 Though a third category of sight distance i.e. Overtaking Sight distance is considered for roads in plains, it is not normally feasible/practicable on hill roads and hence not dealt with.

6.6.6 Application of site distance criteria for summit vertical curve design is covered in para 6.9.4. On valley curves, the sight distance requirement is governed by night visibility which is discussed in para 6.9.5. Sight distance requirements at horizontal curves are dealt with in para 6.8.

6.7 Clearance

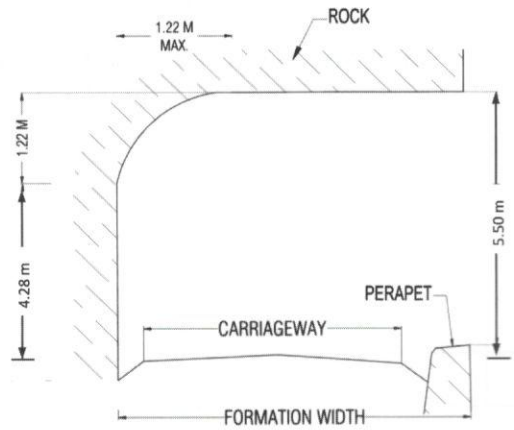
6.7.1 Lateral clearance

6.7.1.1 Desirably the full roadway width at the approaches shall be carried through the underpass. This implies that the minimum lateral clearance (i.e. the distance between the extreme edge of the carriageway and the face of the nearest structure/obstruction) shall be equal to normal shoulder width. On lower category roads in hill areas, having comparatively narrow shoulders, it will be desirable to increase the roadway width at underpasses to a certain extent.

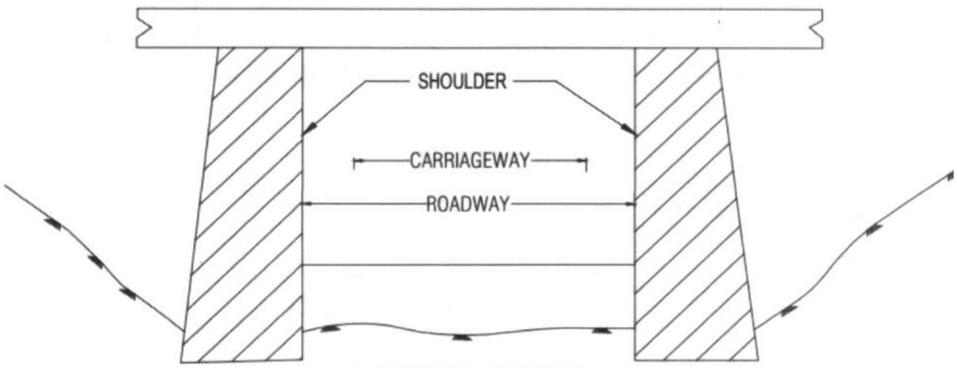
6.7.2 Vertical clearance

6.7.2.1 Minimum vertical clearance of 5.50 meters shall be given over the entire roadway at all underpasses and similarly at overhanging cliffs and semi-tunnel sections. The vertical clearance shall be measured from the highest point of carriageway i.e. crown or superelevated edge to the lowest point of overhead structures/rock out crop. Due allowance for future raising/ strengthening of pavement shall also be made.

6.7.3 **Fig. 6.5 (a)** & **(b)** gives typical details of lateral and vertical clearance on a hill road.



(a) VERTICAL CLEARANCE



(b) HORIZONTAL CLEARANCE

Fig. 6.5 Typical Details of Vertical/Horizontal Clearance

6.8 Horizontal Alignment

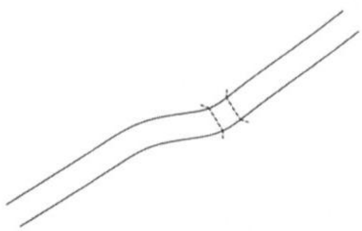
6.8.1 General

6.8.1.1 The horizontal alignment shall be fluent and blend well with the surrounding topography. A flowing line which conforms to natural contours is aesthetically preferable to one with long tangents slashing through the terrain. The horizontal alignment shall be co-ordinated carefully with the longitudinal profile.

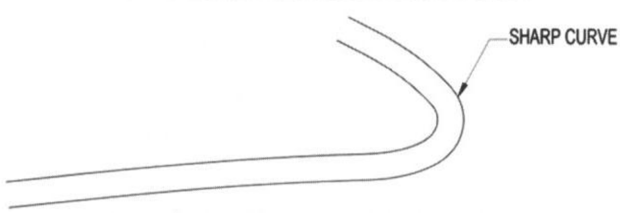
6.8.1.2 Breaks in horizontal alignment at cross-drainage structures and sharp curves at the end of long tangents/straight sections shall be avoided, **Fig. 6.6**.

6.8.1.3 Short curves give appearance of kinks, particularly for small deflection angles, and shall be avoided. The curves shall be sufficiently long and have suitable transitions to provide pleasing appearance.

Curve length shall be atleast 150 meters for a deflection angle of 5 degrees and this shall be increased by 30 meters for each degree decrease in the deflection angle. For deflection angles less than one degree, no curve is required to be designed.



(a) BREAK IN HORIZONTAL ALIGNMENT AT CROSS DRAINAGE STRUCTURE



(b) SHARP CURVE AT THE END OF LONG TANGENT

Fig. 6.6 Bad Aligment

6.8.1.4 Reverse Curves may be needed in difficult terrain by very sparingly used. It shall be ensured that there is no overlap in the Target point of the reserve curves and there is sufficient length between the two curves for introduction of requisite transition curves, **Fig. 6.7**.

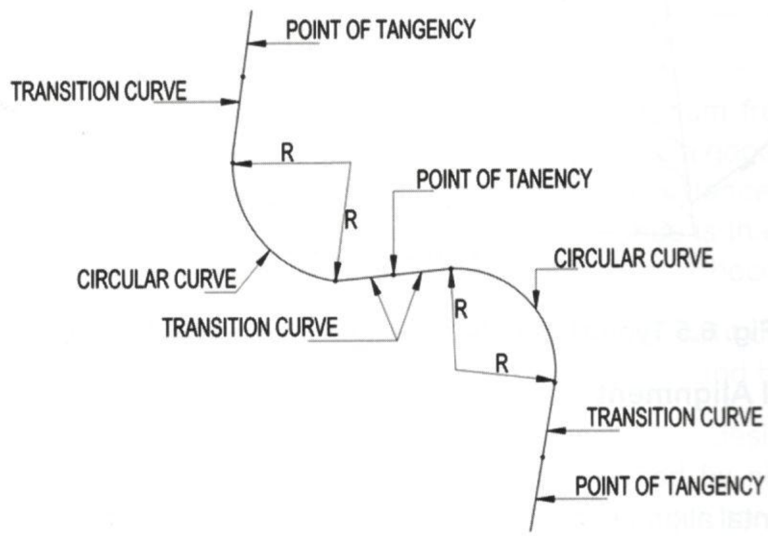


Fig. 6.7 Reverse Curve

6.8.1.5 Curves in the same direction separated by short tangents, known as broken-back curves, shall be avoided as far as possible in the interest of aesthetics and safety and replaced by a single curve. If this is not feasible, a tangent length corresponding to 10 seconds travel time must atleast be ensured between the two curves, **Fig. 6.8**.

6.8.1.6 Compound curves may be used in difficult topography when it is impossible to fit in a single circular curve and in situation where there is sudden restriction in availability of horizontal curve for the design speed. To ensure safe and smooth transition from one curve to the other, the radius of the flatter curve shall not be disproportional to the radius of the sharper curve. A ratio of 1.5:1 shall be considered the limiting value, **Fig. 6.9**.

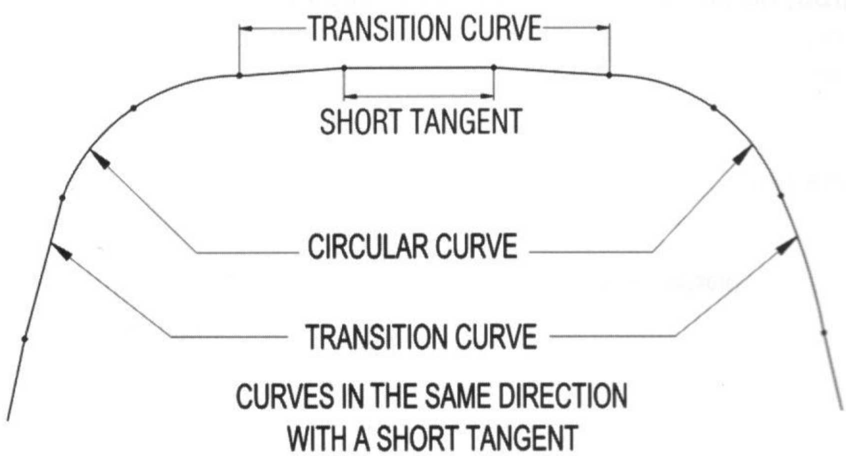


Fig. 6.8 Broken-Back Curve

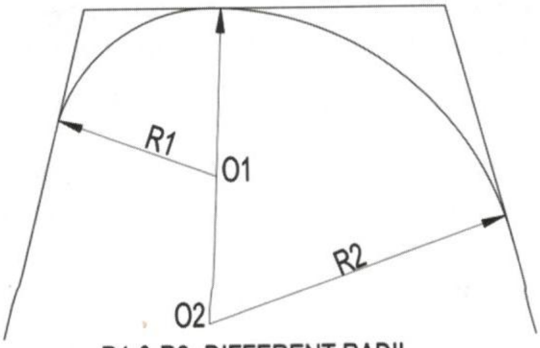


Fig. 6.9 Compound Curve

6.8.1.7 In general, horizontal curves shall consist of circular portion of the curve followed by spiral transitions on both sides. Design speed, super-elevation and coefficient of friction affect the design of curves. Length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of super-elevation.

6.8.2 Superelevation

6.8.2.1 Superelevation is required to be provided at horizontal curves to counter the effects of centrifugal force and is calculated from the formula:

$$e = \frac{V^2}{225R}$$

where

e = superelevation in meter per meter width of roadway

V = speed of vehicle in KMPH and

R = radius of curve in meters

The above formula assumes that the centrifugal force corresponding to three-fourth of design speed is balanced by superelevation and one-fourth counteracted by the side friction between the tyres of vehicles and the road surface.

6.8.2.2 Superelevation obtained from the above formula shall, however, be kept limited to the following values:

a) In snow bound areas 7%

b) In hilly areas not bound by snow 10%

6.8.2.3 The change over from normal section to superelevated section shall be achieved over full length of transition curve. In case transition curve is not there or adequate length cannot be provided due to some reason, two-third superelevation shall be attained on the straight reach and balance on circular curve.

6.8.2.4 From the drainage point of view, the superelevation shall not be less than the camber/ cross fall appropriate to the type of wearing surface. Accordingly, when the value of superelevation

obtained from formula in para 6.8.2.1 above is less than road camber/cross-fall, the letter may be continued on the curved portion without providing any superelevation.

6.8.2.5 Superelevation at culverts in curves

The top surface of the wearing course of culverts shall have the same cross profile as the approaches. The superelevation may be given on the abutments keeping the deck slab thickness uniform as per design. The level of the top of the slab of the culverts shall be the same as the top level of the approaches so that any undue jerk while driving on the finished road is avoided.

6.8.2.6 Radii beyond which no superelevation is required; **Table 6.7** gives the radii of horizontal curves for different camber rates beyond which superelevation will not be required.

Table 6.7 Radii beyond which Superelevation is not required

Design Speed (Km/hr)	**Radii (Meters) for camber of**				
	4%	**3%**	**2.5%**	**2%**	**1.7%**
20	50	60	70	90	100
25	70	90	110	140	150
30	100	130	160	200	240
35	140	180	220	270	320
40	180	240	280	350	420
50	280	370	450	550	650

6.8.2.7 Methods of attaining superelevation

The normal cambered section of the road is changed into superelevated section in two stages First stage is the removal of adverse camber in outer half of the pavement. In the seconc stage, superelevation is gradually built up over the full width of the carriageway so that requirec superelevation is available at the beginning of the circular curve. There are three differen methods for attaining the superelevation: (i). revolving pavement about the centre line; (ii) Revolving pavement about the inner edge; and (iii). revolving pavement about the outer edge **Plate 1** illustrates these methods diagrammatically. The small cross sections at the bottom o each diagram indicate the pavement cross slope condition at different points.

6.8.2.8 Each of the above methods is applicable under different conditions. Method (i) which involves least distortion of the pavement will be found suitable in most of the situation where there are no physical controls, and may be adopted in the normal course. Method (ii). i preferable where the lower edge profile is a major control, e.g. on account of drainage. Wher overall appearance is the criterion, method (iii) is preferable since the outer edge profile, whic is most noticeable to drivers, is not distorted.

6.8.2.9 The superelevation shall be attained gradually over the full length of the transitio curve, so that the design superelevation is available at the starting point of the circular portior Sketches in **Plate 3** have been drawn on this basis. In cases where transition curve canno for some reason be provided, two-third superelevation may be attained on the straight sectio before start of the circular curve and the balance one-third on the curve.

6.8.2.10 In developing the required superelevation, it shall be ensured that the longitudinal slope of the pavement edge compared to the centreline (i.e. the rate of change of superelevation) is not steeper than 1 In 150 for roads in plain and rolling terrain, and 1 in 60 in mountainous and steep terrain.

6.8.3 Minimum curve radii

6.8.3.1 On a horizontal curve, the centrifugal force is balanced by the combined effect of superelevation and side friction. Basic equation for this condition of equilibrium is as follows:

$$\frac{v^2}{gR} = e+f$$

$$\text{or} \quad \frac{V^2}{127(e+f)}$$

where

v = vehicle speed in meters per second

V = vehicle speed in km/hr

g = acceleration due to gravity in meters/sec^2

e = Superelevation in meter

f = Coefficient of side friction between vehicle tyre and pavement (taken as 0.15)

R = Radius in meters

Based on this equation and maximum permissible value of superelevation, radii for horizontal curves corresponding to ruling minimum and absolute minimum design speeds are given in **Table 6.8**.

Table 6.8 Minimum Radii of Horizontal Curves for Various Classes of Hill Roads

Classification	Mountainous Terrain				Steep Terrain			
	Areas not affected by snow		Snow bound areas		Areas not affected by snow		Snow bound areas	
	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)
National Highways and State Highways	80	50	90	60	50	30	60	33
Major District Roads	50	30	60	33	30	14	33	15
Other District Roads	30	20	33	23	20	14	23	15
Village Roads	20	14	23	15	20	14	23	15

Note: Ruling minimum and Absolute Minimum Radii are for ruling design speed and minimum design speed respectively.

6.8.4 Transition curve

6.8.4.1 *Transition curves are necessary for a vehicle to have smooth entry from a straight* section into a circular curve. The transition curves also improve aesthetic appearance of the road besides permitting gradual application of the *superelevation and extra widening of carriageway* needed at the horizontal curves. Spiral curve shall be used for this purpose.

6.8.4.2 Minimum length of the transition curve shall be determined from the following two considerations and the larger of the two values adopted for design.

i) The rate of change of centrifugal acceleration shall not cause discomfort to drivers. From this consideration, the length of transition curve is given by:

$$L_s = \frac{0.0215\ V^3}{CR}$$

where

L_s = length of transition in meters

V = speed in km/h

R = radius of circular curve in meters

C = 80/(75+V)(subject to a maximum of 0.8 and minimum of 0.5)

ii) The rate of change of superelevation (i.e. the longitudinal grade developed at the pavement edge compared to through grade along the centre line) shall be such as not to cause discomfort to travelers or to make the road appear unsightly. The formulae for minimum length of transition on this basis are:

For Plain and Rolling Terrain:

$$L_s = \frac{2.7\ V^2}{R}$$

For Mountainous and Steep Terrain:

$$L_s = \frac{1.0\ V^2}{R}$$

6.8.4.3 Having regard to the above considerations, the minimum transition lengths for different speeds and curve radii are given in **Table 6.9**.

6.8.4.4 The elements of a combined circular and transition curve are illustrated in **Fig. 6.10**. For deriving values of the individual elements like shift, tangent distance, apex distance, etc. and working out coordinates to lay the curves in the field, it is convenient to use curve tables. For this reference may be made to IRC:38 "Guidelines for Design of Horizontal Curves for Highways and Design Tables".

Table 6.9 Minimum Transition Length for Different Speeds and Curve Radii

Curve Radius (meter)	Design Speed (km/h)				
	50	**40**	**30**	**25**	**20**
15				NA	30
20				35	20
25			NA	25	20
30			30	25	15
40		NA	25	20	15
50		40	20	15	15
55		40	20	15	15
70	NA	30	15	15	15
80	55	25	15	15	NH
90	45	25	15	15	
100	45	20	15	15	
125	35	15	15	NR	
150	30	15	15		
170	25	15	NR		
200	20	15			
300	15	NR			
400	15				
500	NR				

Note: NA – Not applicable
NR: Transition not required

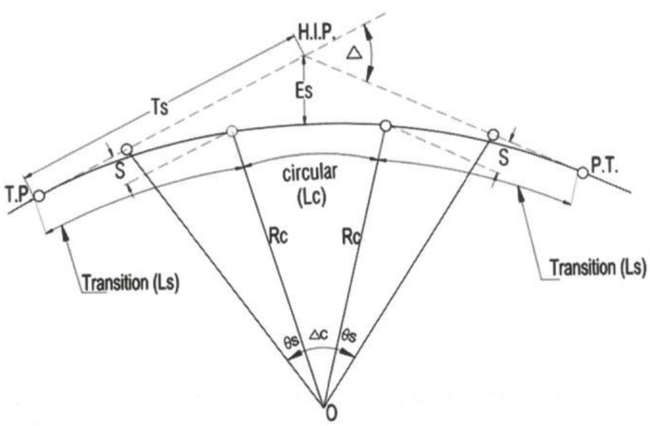


Fig. 6.10 Elements of a Combined Circular and Transition Curve

TANGENT POINT ..........................T.P. P.T.
HORIZONTAL INTERSECTION POINT ....H. I. P.
TOTAL DEVIATION ANGLE......................Δ
DEVIATION AND CENTRAL ANGLE OF CIRCULAR ARC ....Δc
DEVIATION ANGLE OF TRANSITION CURVE............................θs
RADIUS OF CIRCULAR CURVE.............Rc
SHIFT .... s
TANGENT DISTANCE ....Ts
APEX DISTANCE ....Es
LENGTH OF TRANSITION ....Ls
LENGTH OF CIRCULAR CURVE Lc

6.8.5 Widening at curves

6.8.5.1 At sharp horizontal curves, it Is necessary to widen the carriageway to facilitate safe passage of vehicles. The widening has two components i.e. Mechanical widening to compensate the extra width occupied by the vehicle due to tracking of rear wheels and Psychological widening to permit easy crossing of vehicles, since vehicles tend to wander more on curve. Both the components are to be taken care of in double lane and mechanical components on single lane roads. However, at blind curves double-laning may be considered.

6.8.5.2 Extra width to be provided on horizontal curves is given in **Table 6.10**.

Table 6.10. Widening of Pavement at Curves

Radius of Curve (m)	**Upto 20**	**21 to 40**	**41 to 60**	**61 to 100**	**101 to 300**	**Above 300**
Extra Width (m)						
Two Lane	1.5	1.5	1.2	0.9	0.6	Nil
Single-Lane	0.9	0.6	0.6	Nil	Nil	Nil

6.8.5.3 Extra width shall be given by increasing the width at uniform rate along transition curve and full width given along circular curve. Entire widening shall preferably be provided on inside of the curve. The extra widening may be attained by means of offsets radial to the centre line. It shall be ensured that the pavement edge lines are smooth and there is no apparent kink.

6.8.6 Set-back distance at horizontal curves

6.8.6.1 Requisite sight distance shall be available to sight the inside of horizontal curves. Lack of visibility in the lateral direction may arise due to obstructions like walls, cut slopes, wooded areas, high crops, etc. Set-back distance from the centre line of the carriageway, within which offending obstructions shall be cleared, to ensure the needed visibility, can be determined as given in para 6.8.6.2. However, in certain cases, due to variations in alignment, road cross-section and the type and location of obstructions, it may become necessary to resort to field measurements to fix the exact limits of clearance.

6.8.6.2 The set-back-distance is calculated from the following equation (see **Fig. 6.11** for definitions):

$$\mathbf{m = R-(R-n)\ Cos\ \theta}$$

where = $\theta = \frac{S}{2(R-n)}$ radians;

m = the minimum set-back distance to sight obstruction in meters (measured from the centre line of the road);

R = radius at centre line of the road in meters

n = distance between the centre line of the road and the centre line of the inside lane in meters; and

S = sight distance in meters

In the above equation, sight distance is measured along the middle or inner lane. On single-lane roads, sight distance is measured along centre line of the road and 'n' is taken as zero.

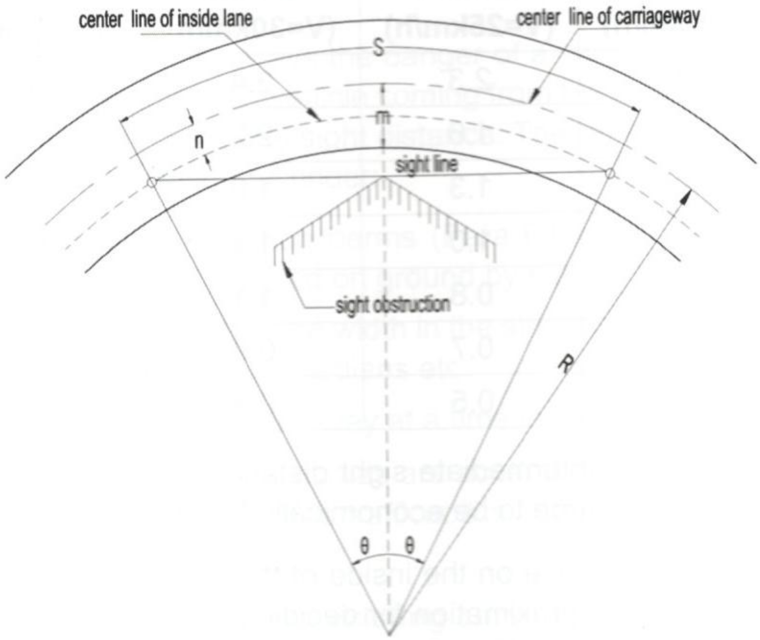


Fig. 6.11 Visibility at Horizontal Curves

R – RADIUS OF CURVE

S – SIGHT DISTANCE

m – MINIMUM SET-BACK DISTANCE

n – DISTANCE BETWEEN CENTRE LINE OF CARRIAGEWAY AND CENTRE LINE OF INSIDE LANE

6.8.6.3 Utilising the above equation, the design values for set-back distance corresponding to safe stopping distance for single lane carriageway are given in **Table 6.11**. These design values relate basically to circular curves longer than the design sight distance. For shorter curves, the values of set-back distance given in **Table 6.11** will be somewhat on the higher side, but these can, however, be used as a guide. Lateral clearances for two lane carriageway can be computed similarly from the above equation.

Table 6.11 Recommended Set-back Distance for Single-Lane Carriageway

Radius of Circular Curve in Meters	Set-Back Distance in Meters				
	S=20m (V=20km/h)	S=25m (V=25km/h)	S=30m (V=30km/h)	S=45m (V=40km/h)	S=60m (V=50km/h)
14	3.4	-	-	-	-
15	3.2	-	-	-	-
20	2.4	3.8	-	-	
23	2.1	3.3	-	-	
30	1.7	2.6	3.7	-	-

Radius of Circular Curve in Meters	Set-Back Distance in Meters				
	S=20m (V=20km/h)	S=25m (V=25km/h)	S=30m (V=30km/h)	S=45m (V=40km/h)	S=60m (V=50km/h)
33	1.5	2.3	3.4	-	-
50	1.0	1.6	2.2	5.0	-
60	-	1.3	1.9	4.2	-
80	-	1.0	1.4	3.1	5.6
100	-	0.8	1.1	2.5	4.5
120	-	0.7	0.9	2.1	3.7
150	-	0.5	0.8	1.7	2.3

6.8.6.4 Lateral clearance for intermediate sight distance can be computed similarly but the set-back required is usually too large to be economically feasible in the case of hill roads.

6.8.6.5 Where there is a cut slope on the inside of the horizontal curve, the average height of sight line can be used as an approximation for deciding the extent of clearance. For stopping sight distance, this may be taken as 0.7 m. Cut slopes shall be kept lower than this height at the line demarcating the set-back distance envelope, either by cutting back the slope or benching suitably, **Fig. 6.12**. Such a provision is also generally known as better benching or vision berms.

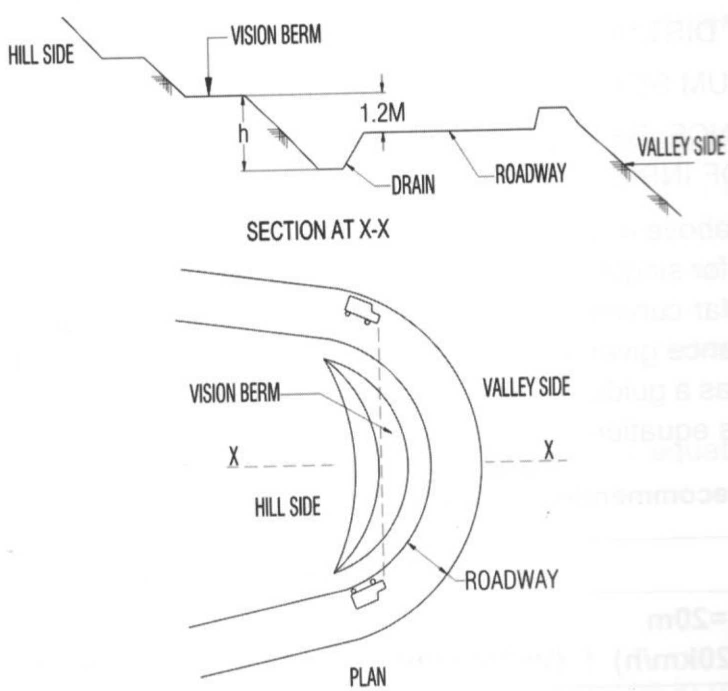


Fig. 6.12 Vision of Berms

6.8.7 Blind curves

6.8.7.1 Blind curves are those on which sight distance available is less than the safe stopping sight distance i.e. absolute minimum from safety point of view. While clearance of obstructions within the minimum set-back distance is expected to ensure the minimum sight distance required

as per standards, in hill roads it may not always be possible to ensure this due to terrain conditions. In such cases certain curves will have sight distance less than minimum as per standards and hence blind.

6.8.7.2 In a blind curve there is always the danger of a vehicle not being able to come to a stop before reaching danger point or a vehicle coming from the opposite direction which is likely to collide with it, due to lack of adequate sight distance. The remedy for this problem, to ensure better traffic safety, may be provided as under:

a) better benching or vision berms (Para 6.8.6.5 & **Fig. 6.12** refers) in a more liberal manner as required on ground by survey.

b) making the road two - lane width in the stretch and providing lane dividers in the form of central studs or medians etc.

c) restriction of traffic to one way at a time in the stretch, if otherwise practicable.

6.8.7.3 It has to be ensured at blind curves are accepted only where it is un-avoidable and that also rarely in any stretch of road since trafficability and safety of a hill road is considerably reduced by blind curves.

6.8.8 Measurement of radius of an existing curve at site

6.8.8.1 It is often necessary to know radius of an existing curve on a hill road to plan improvements etc. As it may not always be possible to reach the centre of curve, an indirect method may have to be adopted.

A simple method is given in **Fig. 6.13**.

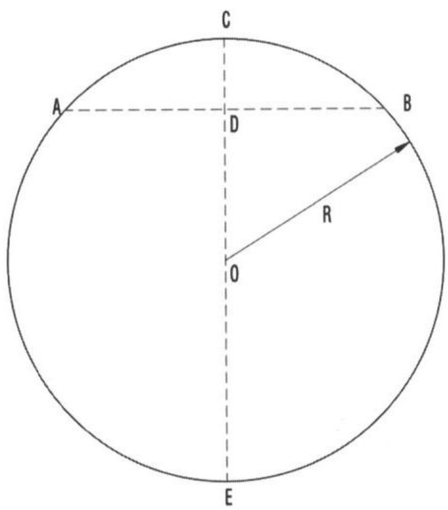


Fig. 6.13 At site Measurement of Radius of Existing Curve

Measure any chord AB and offset DC

Now AD x DB = CD x DE

$(1/2 \text{ chord})^2 = \text{offset} \times (2R - \text{offset})$

$= 2R \text{ offset} - \text{offset}^2$

ignoring offset^2; $1/4 \text{ chord}^2 = 2R \text{ offset}$

or

$$R = \frac{\text{Chord}^2}{8\ \text{Offset}}$$

6.9 Vertical Alignment

6.9.1 General

6.9.1.1 Broken-back grade lines, i.e. two vertical curves in the same direction separated by a short tangent, shall be avoided due to poor appearance, and preferably replaced by a single curve.

6.9.1.2 Decks of small cross-drainage structures (i.e. culverts and minor bridges) shall follow the same profile as the flanking road section, with no break in the grade line.

6.9.1.3 Recommended gradients for different terrain conditions, except at hair-pin bends, are given in **Table 6.12**.

Table 6.12 Recommended Gradients for Different Terrain Conditions

Classification of Gradient	Mountainous Terrain and Steep Terrain more than 3000 m above MSL	Steep terrain up to 3000 m height above MSL
Ruling Gradient	5% (1 in 20.0)	6% (1 in 16.7)
Limiting Gradient	6% (1 in 16.7)	7% (1 in 14.3)
Exceptional	7% (1 in 14.3)	8% (1 in 12.5)

6.9.1.4 Gradients up to the 'ruling gradient' may be used as a matter of course in design.

6.9.1.5 The 'limiting gradients' may be used where the topography of a place compels this course or where the adoption of gentler gradients would add enormously to the cost. In such cases, the length of continuous grade steeper than the ruling gradient shall be as short as possible.

6.9.1.6 'Exceptional gradients' are meant to be adopted only in very difficult situations and for short lengths not exceeding 100 m at a stretch. Successive stretches of exceptional gradients must be separated by a minimum length of 100 m having gentler/flatter gradient.

6.9.1.7 The cumulative rise/fall in elevation over 2 km length shall not exceed 100 m in mountainous terrain and 120 m in steep terrain.

6.9.1.8 *Escape lane:* Where long, continuous descending grades exist or where topographic and location controls require such grades on new alignment for a length of 2 kms or more, the design and construction of an emergency escape ramp at an appropriate location with an interval of about 2 kms is desirable for the purpose of slowing and stopping an out-of-control vehicle away from the main traffic stream. These lanes may be useful in bringing the vehicles to halt in case of emergency due to brake failure. The lanes are constructed with reverse gradients to provide deceleration of vehicles with arrester bed suitably located. Specific guidelines for the design of escape lanes are lacking at this time. However, guiding principle for design and layout of escape lane as per AASHTO practice is appended (**Appendix-3**).

6.9.1.9 *Climbing lane:* Restricted overtaking opportunities and the presence of slow moving vehicles can result in substantial congestion and high accident rates through injudicious overtaking. Congestion effects are greatest on long steep gradients. The situation is particularly difficult in India because of the presence of overloaded trucks and buses with very low power-to-weight ratios.

In such circumstances, the provision of an auxiliary climbing lane can be extremely beneficial to enable vehicles travelling up the gradient to overtake safety and efficiently.

Thus climbing lanes may be provided wherever necessary in order to address the necessity of making available a separate lane for safe overtaking for vehicle travelling uphill, in reaches having continuous exceptional gradients.

Clear signing, road marking and in some cases, physical barriers are needed to ensure that the absolute right of way of climbing vehicles is safely upheld.

6.9.2 Grade compensation at curves

6.9.2.1 At horizontal curves, the gradients shall be eased by an amount known as 'grade compensation' which is intended to offset the extra tractive effort involved at curves. This is calculated by the following formula:

Grade compensation (per cent) = $\frac{30 + R}{R}$

subject to maximum of 75/R where R is radius of the curve in meters. Since grade compensation is not necessary for gradients flatter than 4 per cent, when applying grade compensation correction, the gradients need not be eased beyond 4 per cent.

6.9.3 Vertical curve

6.9.3.1 Vertical curves are introduced for smooth transition at grade changes. Convex vertical curves are known as summit curves and concave vertical curves as valley or sag curves. Both these shall be designed as square parabolas.

6.9.3.2 The length of the vertical curve is controlled by sight distance requirements, but curves with greater length are aesthetically better.

6.9.3.3 Curves shall be provided at all grade change exceeding those indicated in **Table 6.13**. For satisfactory appearance, the minimum length shall be as shown in the Table.

Table 6.13 Minimum Length of Vertical Curves

Design Speed (km/h)	Maximum Grade Change (percent) not requiring a vertical curve	Minimum length of vertical curve (m)
Upto 35	1.5	15
40	1.2	20
50	1.0	30

6.9.3.4 Where horizontal and summit vertical curves overlap, the design shall provide for the required sight distance both in the vertical direction along the pavement and in the horizontal direction on the inside of the curve.

6.9.4 Summit curves (Fig. 6.14)

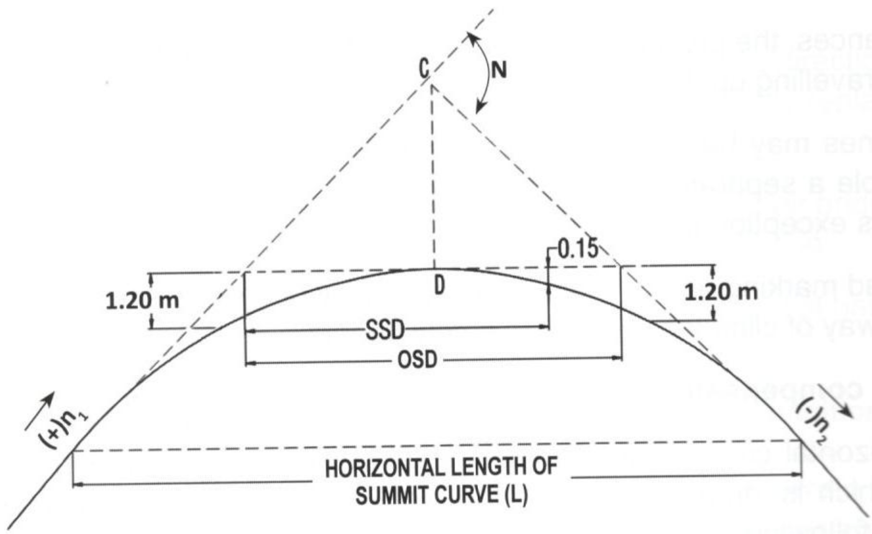


Fig. 6.14 Summit Curve

SSD = STOPPING SIGHT DISTANCE

OSD = OVERTAKING SIGHT DISTANCE

h = HEIGHT OF OBJECT ABOVE PAVEMENT SURFACE 0.15m

H = HEIGHT OF EYE LEVEL OF DRIVER OVER PAVEMENT SURFACE 1.2m

N = DEVIATION ANGLE

n_1 = ASCENDING GRADIENT

n_2 = DESCENDING GRADIENT

6.9.4.1 The length of summit curves is governed by the choice of sight distance. The length is calculated on the basis of the following formulae.

a. For safe stopping sight distance

Case (i) When the length of the curve exceeds the required sight distance, i.e. L is greater than S.

$$L = \frac{NS^2}{4.4}$$

where

N = Deviation angle, i.e. the algebraic difference between the two grades

L = Length of parabolic vertical curve in meters

S = Sight distance in meters

Case (ii) When the length of the curve is less than the required sight distance, i.e. L is less than S.

$$L = 2S - \frac{4.4}{N}$$

b. For intermediate sight distance

Case (i) When the length of the curve exceeds the required sight distance, i.e. L is greater than S.

$$L = \frac{NS^2}{9.6}$$

Case (ii) When the length of the curve is less than the required sight distance, i.e. L is less than S.

$$L = 2S - \frac{9.6}{N}$$

6.9.4.2 The length of summit curve for various cases mentioned above can be read from **Plates 2** & **3**. In these Plates, value of the ordinate "**M**" to the curve from the intersection point of grade lines is also shown.

6.9.5 Valley curves (Fig. 6.15)

6.9.5.1 The length of valley curves shall be such that for night travel, the head light beam distance is equal to the stopping sight distance. The length of curve may be calculated as under:

Case (i) When the length of the curve exceeds the required sight distance, i.e. L is greater than S.

$$L = \frac{NS^2}{1.50 + 0.035\ S}$$

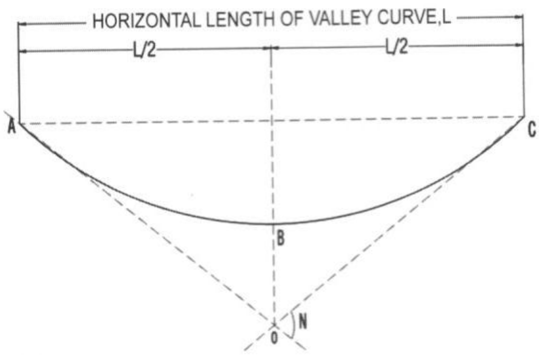


Fig. 6.15 Valley Curve

Case (ii) When the length of the curve is less than the required sight distance, i.e. L is less than S.

$$L = 2S - \frac{1.5 + 0.35\ S}{N}$$

In both cases

N = deviation angle, i.e. the algebraic difference between the two grades

L = length of parabolic vertical curve in meters

S = stopping sight distance in meters

6.9.5.2 Length of valley curve for various grade differences is given in graphical form in Plate 4.

6.10 Design Criteria for Hair-Pin Bends (Fig 6.16)

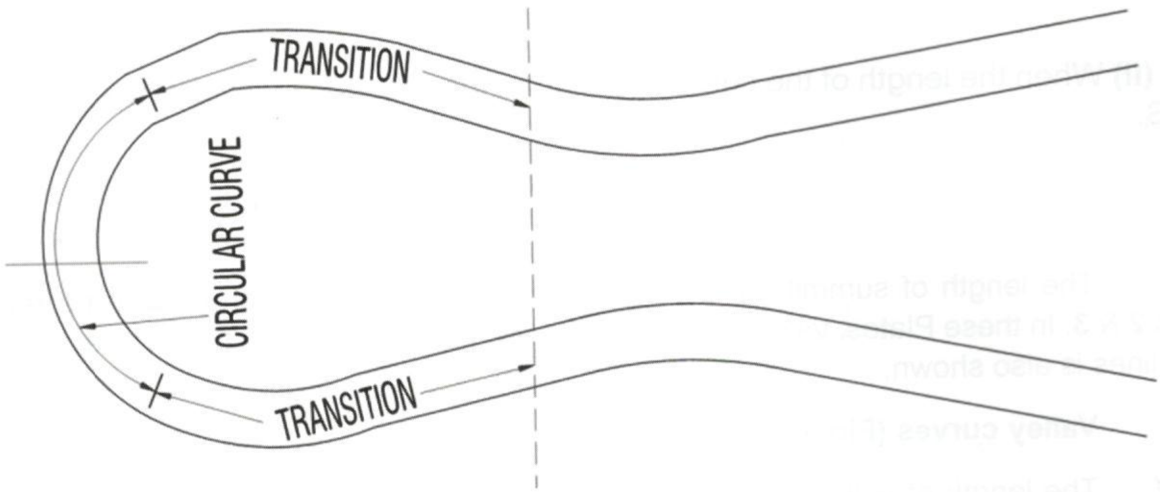


Fig. 6.16 Hair Pin Bend

6.10.1 Hair-pin bends, where unavoidable, may be designed either as a circular curve with transition at each end, or as a compound circular curve. The following criteria shall be followed normally for their design:

a) Minimum design speed	-	20 km/h
b) Minimum roadway, width at apex		
i. National/State Highways	-	11.5 m for double-lane
	-	9.0 m for single-lane
ii. Major District Roads and Other District Roads	-	7.5 m
iii. Village Roads	-	6.5 m
c) Minimum radius for the inner curve	-	14.0 m
d) Minimum length of transition curve	-	15.0 m
e) Gradient	-	1 in 40
Maximum		(2.5%)
Minimum	-	1 in 200
		(0,5%)
f) Superelevation	-	1 in 10
		(10%)

6.10.2 Inner and outer edges of the roadway shall be concentric with respect to centre line of the pavement. Where a number of hair-pin bends have to be introduced, a minimum intervening distance of 60 m shall be provided between the successive bends to enable the driver to negotiate the alignment smoothly.

6.10.3 Widening of hair-pin bends subsequently is a difficult and costly process. Moreover, gradients tend to become sharper as generally widening can be achieved only by cutting the hill side. These points shall be kept in view at the planning stage, especially if a series of hair-pin bends are involved.

6.10.4 At hair-pin bends, preferably, the full roadway width shall be surfaced.

6.10.5 A cross drainage to be provided 20 m before the start of the hair-pin bend for proper drainage of surface water. Similarly adequate drainage may also be provided on the hill side of the bend so that water does not cross over it. **Plate 5**

6.11 Passing Places (Fig. 6.17)

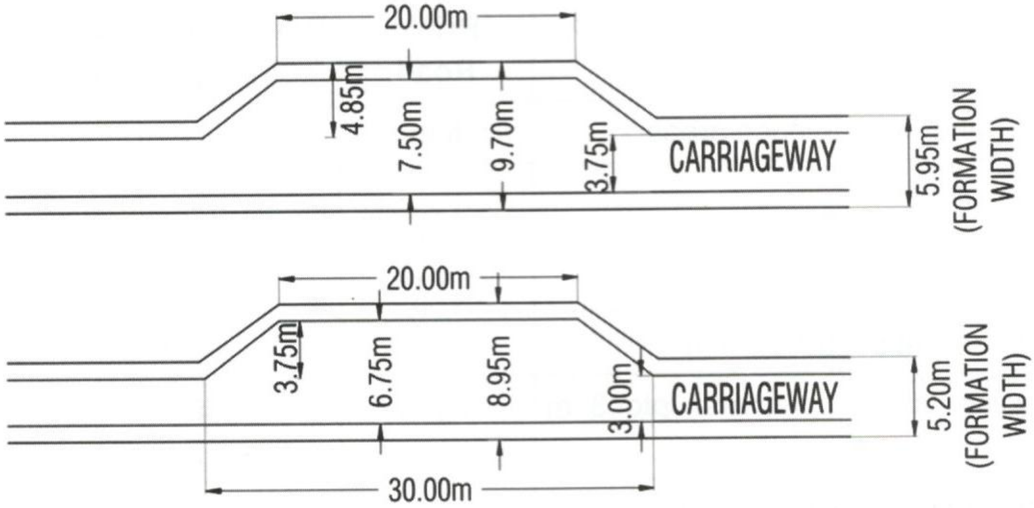


Fig. 6.17 Passing Places ODR & VR

6.11.1 Passing places are required on single lane hill roads to facilitate crossing of vehicles approaching from the opposite direction and to tow aside a disabled vehicle so that it does not obstruct traffic. They shall be provided at the rate of 2-3 per kilometer.

6.11.2 Normal size of passing place is 3.75 m wide, 30 m long on inside edge and 20 m long on the farther side. The exact location of passing places shall be judiciously determined taking into consideration the available extra width and visibility.

6.12 Co-ordination of Horizontal and Vertical Alignments

6.12.1 The overall appearance of a highway can be enhanced considerably by judicious combination of the horizontal and vertical alignments. Plan and profile of the road shall not be designed independently but in unison so as to produce an appropriate three dimensional effect. Proper co-ordination in this respect will ensure safety, improve utility of the highway and contribute to overall aesthetics.

6.12.2 Vertical curvature superimposed upon horizontal curvature gives a pleasing effect. As such the vertical and horizontal curves shall coincide as far as possible and their length shall be more or less equal. If this is difficult for any reason, the horizontal curve shall be somewhat longer than the vertical curve.

6.12.3 Sharp horizontal curves shall be avoided at or near the apex of pronounced summit/ slag vertical curves from safety point of view.

6.13 Bridle Roads and Bridle Paths

As earlier brought out in para 4.4.3, the Isolated villages habitations can be connected by bridle roads. Bridle paths are also provided in border areas (generally called border tracks or village tracks). These may also be necessary for pockets of very small population in remote areas. Typical specifications of Bridle road, Bridle path and Operational tracks (OP tracks) are given in **Table 6.14**.

Table 6.14 Specifications of Bridle Road and Bridle Path

Sl. No.	Items	Bridle Road	Bridle Path (Border/ Village Track)	OP Track
1.	Road Land width in open areas	6 m	3.0 m	4.00 m
2.	Formation width a. Normal b. Exceptional	 2 m 1.7 m	 1.0 m 0.8 m	 2.75 m
3.	Radius of Curves (Minimum)	5 m	5 m	12 m
4.	Widening at sharp curves upto 3 m radius	1.0 m	0.3 m	1.5 m
5.	Inside slope (cross fall)/Camber	3 to 4%	3 to 4%	
6.	Minimum radius at H.P. Bends	3.0 m	1.0 m	
7.	Gradients a. For Ghat tracing	 12%	 -	 Ruling
	b. Ruling	17%	17%	1:15 Max
	c. Limiting	-	25%	1:10
	d. Exceptional (not more than 30 m Length)	25%	30%	May be upto 1 in 7
8.	Drains	0.30 m	0.2 m	0.50
9.	Scuppers	1 m span 3 to 10 Nos. per km	0.6 m span 3 to 5 Nos. per km	
10.	Bridges and Culverts a. Design load b. Clear roadway between kerbs	 400 kg/sqm 2.0 m	 400 kg/sqm 1.0 m	

Sl. No.	Items	Bridle Road	Bridle Path (Border/ Village Track)	OP Track
11.	Surface	Un-surfaced. In slushy stretches stone/brick paving or some other treatment		

6.14 Ropeway Bridge

In remote area, ropeway foot bridges may also be considered to provide connectivity as per needs.

7 TUNNELS

Tunnels become economical and, therefore, necessary while developing an alignment for hill road passing through high ground. Tunnels are also constructed under a river or waterway, mostly in an urban area. For detailed planning and design, IRC:SP:91 be referred. However, preliminary steps for tunnel planning are as follows:

7.1 Surveys

Topographical survey helps in identifying land features and for selecting the most suitable tunnel alignment. Traverse network connecting the existing survey control on each side of the hill to a high degree of accuracy is necessary for establishing the ground control for the tunnel alignment.

7.2 Accuracy

Director, Geodetic and Research Branch, Survey of India have issued technical instructions regarding horizontal control survey for tunnels, where it is stated that an accuracy of 1:30,000 for outer horizontal control should be aimed at.

7.3 Mapping

The mapping around both the proposed portal locations shall be conducted by EDM survey for maintaining the desired accuracy. Sufficient area around both the portal locations shall be covered on a scale of 1:1000 with a contour interval of 1 m to have a better appreciation of the topography around the portal location for planning the suitable geometry of the tunnel alignment and location of portals, bore hole locations and other permanent structures. Proposed tunnel alignment shall also be marked on the contour plans prepared around both portal locations.

7.4 Ideal Tunnel Portal Layout

The important criteria for locating the portal are the existence of sound rock conditions with adequate cover. The rock mass should be free from any fault/dislocation and the loose fractured zones/layers should not be sloping towards the portals. Further, the location of a portal should be such that it is not affected by landslides ensuring the approaches to the portal in stable formation requiring least open cut excavation/ground stabilization measures.

7.5 Geological and Geophysical Studies

These studies should be got conducted by an expert geologist and should include:

- Geomorphology
- Regional Geology
- Rock Structure
- Seismicity of the location and neighbouring area

7.6 Geological Study of Tunnel Site

These will include:

- General Geology
- Geophysical Investigations
- Discussion of the results of these studies, and
- Conclusion

7.7 Design Standards

(i) **Alignment in plan:** A road tunnel should, ideally be straight in plan. This is seldom possible, but the introduction of sharp curves, particularly in conjunction with steep gradients should be avoided, even if it means a longer tunnel. If horizontal curves become unavoidable, a minimum radius of 200 m could be adopted. Only in exceptional cases, this should be reduced to 100 m.

(ii) **Gradients:** The gradients of the roadway are of primary importance, since in most cases they constitute a determining factor in the length of tunnel, and hence its cost. In general, it is sought to employ gradients which will not cause congestion through the excessive slowing down of heavy vehicles.

(iii) **Cross-section of tunnel:** The internal cross-sectional dimensions of a road tunnel are determined by the following considerations:

(a) the number and width of traffic lanes making up the carriageway;

(b) the vertical headroom for vehicles;

(c) the space to be provided for ventilation ducts, walkways, lighting, and drainage and for fire and other services.

Long tunnels should have a good longitudinal gradient for effective drainage, 0.2 per cent is satisfactory. Long tunnels, which are more than 300 m length, should not have a gradient steeper than 4 per cent. With tunnels less than 300 m long, a straight fall should be adopted. However, two outward falling gradient are permitted for a tunnel over 300 m long.

(iv) **Ventilation:** Ventilation is one of the most important factors in the design of road tunnels. There are two main requirements:

(1) A sufficient volume of fresh air must be supplied to all parts of the traffic space to dilute the carbon monoxide from motor exhausts to a biologically safe level.

(2) A good standard of visibility must be maintained in the tunnel for the safety and comfort of drivers.

Road vehicles passing through a tunnel emit fumes, which need to be cleared quickly. Artificial ventilation becomes necessary in tunnels above 400 m length. The ventilation system should be capable of producing a fresh air input of 0.5 cum per meter length of the tunnel. The speed of air is generally limited to 5 m per second.

(v) **Illumination:** The lighting of tunnels calls for special consideration. The driver entering a tunnel should be able to adjust himself to the artificial lighting conditions inside the tunnel. Similarly, the driver leaving a tunnel should be able to adjust himself to the natural light outside the tunnel. For achieving these requirements, the tunnel is divided into zones of different lighting intensities.

APPENDIX-1

MAIN POINTS FOR DATA COLLECTION DURING GROUND RECONNAISSANCE

1. Details of route vis-à-vis topography of the area
2. Length of the road
3. Bridging requirements – number, length
4. Geometrics:
   (a) Gradients
   (b) Curves, hair-pin bends, etc.
5. Existing means of communication-mule path, jeep track, etc.
6. Right-of-way, bringing out constraints on account of built-up area, monuments, and other structures.
7. Terrain and soil conditions
   7.1 Geology of the area
   7.2 Nature of the soil
   7.3 Road length passing through:
      (i) Mountainous terrain
      (ii) Steep terrain
      (iii) Rocky stretches with indication of the length in loose rock stretches
      (iv) Areas subject to avalanches and snowdrifts
      (v) Slip-prone areas
   7.4 Cliffs and gorges
   7.5 Drainage characteristics of the area including susceptibility to flooding
   7.6 General elevation of the road indicating maximum and minimum heights negotiated by main ascents and descents.
   7.7 Total number of ascents and descents
   7.8 Vegetation – extent and type.
8. Climatic conditions
   8.1 Temperature-monthly maximum and minimum readings
   8.2 Rainfall data-average annual, peak intensities monthly distribution (to the extent available)
   8.3 Snowfall data-average annual, peak intensities, monthly distribution (to the extent available)
   8.4 Wind direction and velocities
   8.5 Fog conditions

8.6 Exposure to sun

8.7 Unusual weather conditions, like cloud bursts, etc.

9. Facilities/Resources

9.1 Landing ground

9.2 Dropping zones

9.3 Food stuffs

9.4 Labour-local availability and need for import

9.5 Construction materials (timber, bamboo, sand, stones, shingle, etc.) extent of their availability and stones, shingle, etc.) extent of their availability and leads involved.

10. Value of land – agriculture land, irrigated land, built up land, forest land, etc.

11. Approximate construction cost

12. Access points indicating possibility of induction of equipment

13. Period required for construction

14. Strategic considerations

15. Recreational potential

16. Important villages, towns and marketing centers to be connected

17. Economic factors

(i) Population served by the alignment

(ii) Agricultural and economic potential of the area

18. Other major developmental projects being taken up in the area e.g. hydroelectric projects

19. Miscellaneous, such as, camping sites, law and order problems, royalty charges, availability of contractors for collection and carriage of construction materials, working period available for constructions work, etc.

APPENDIX-2

GENERAL POINTS FOR COMPARISON OF ROUTES

No.	Details	Route No. 1	Route No. 2	Route No. 3	Route No. 4	Remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)

1. Annual Rainfall Data
2. Weather Condition and Period of Working Season
3. Length of Strip
4. Nature of Soil
5. Camp Sites
6. Landing Grounds
7. Dropping Zones
8. Existing Means of Inter Communication
9. Right of Way
10. Gradients
11. Length of Gentle Slopes
12. Length of Forests Affected
13. Length of Cliffs
14. Length of Rocks
15. Length of Agriculture Land
16. Length of Loose Rocks/Avalanche
17. Length of Land Slides
18. Length of Unstable Areas
19. Length of Heavy Clearing
20. Length of Steep Slopes
21. Length of Marshy Area
22. Availability of Road Construction Materials
23. No. and Width of Rivers/Nallahs to be Bridged

24. No. of Hairpin Bends
25. No. of Villages
26. Availability of Labour
27. Hostile Activities if any
28. Total Length of Bridges
29. Important Town and Marketing Centres Connected
30. Maximum Altitude Crossed Enroute
31. Any Other Information
32. Approximate Cost of Construction
33. Maintenance Problems if any

APPENDIX-3

GUIDING PRINCIPLES OF PROVIDING ESCAPE LANE

Highway alignment, gradient, length and descent speed contributes to the potential for out of control vehicles. Accident experience and vehicle operations (usually truck) on the grade combined with engineering judgment are frequently used as the determinant for an escape ramp. Escape lanes may be built at any feasible location where the main road alignment is in transition. They should be built in advance of main lane curvature that cannot be negotiated safely by an out of control vehicle and in advance of populated areas. Escape lanes should exit to be left side of the main line. For new and existing facilities and until local criteria are available it may be useful to adopt the AASHTO criteria. The most commonly used escape ramp is the ascending type with an arrester bed, **Fig. A.2.1**. Ramp installations of ascending type use gradient resistance to advantage, supplementing the effects of the aggregate in the arrester bed, and generally reducing the length of ramp necessary to stop the vehicle. The loose bedding material in arrester bed increases the rolling resistance and bedding serves to hold the vehicle in place on the ramp grade it has came to stop. Escape ramp should be designed for speed range of 50 to 120 km per hour. The design of escape lane should consider the following criteria:

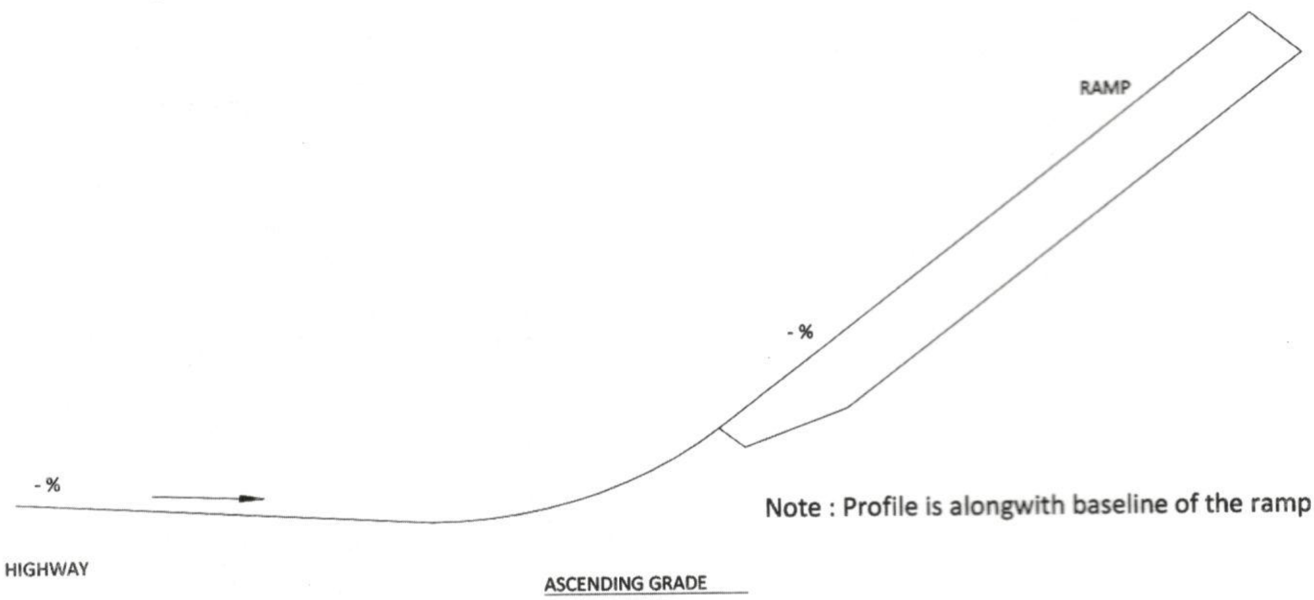
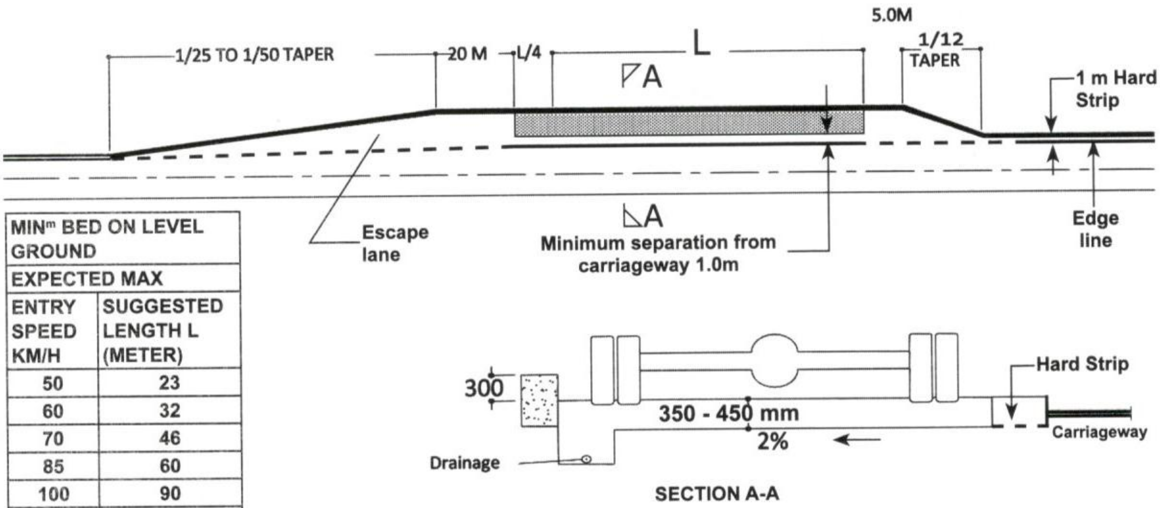


Fig. A.2.1 Typical Type of Emergency Escape Ramp

- Safety stop an out-of-control vehicle and the length of ramp must be sufficient to dissipate the kinetic energy of the moving vehicle.
- Alignment of escape ramp should be tangent or be very flat curvature to relieve the driver of undue vehicle control problems.
- Width of ramp should be adequate to accommodate more than one vehicle because it is not uncommon for two or more vehicles to have need of the escape

ramp within a short time. 9 to 12 m width would more safely accommodate two-or more out of control vehicles. Widths of ramps in use range from 3.6 m to 12 m.

- Surfacing material used in arrester bed should be clean, easily compacted and have high coefficient of rolling resistance. Layout of arrester bed adjacent to carriageway is shown in **Fig. A.2.2**.
- Entrance to the ramp must be designed so that vehicle traveling at a high rate of speed can enter safely.
- Advance sign is required to inform the driver about the existence of the escape ramp well in advance so that a decision whether or not to use the ramp may be taken. Regulatory sign near the entrance should be used to discourage other motorists from entering, stopping or parking at the ramp. Proper illumination of the approach is desirable.
- The characteristic that makes a truck escape ramp an effective safety device also makes it difficult to retrieve a vehicle captured by the ramp. Ideally a service road located adjacent to arrester bed is needed so that recovery vehicle and maintenance vehicles can use it without becoming trapped in the material. Width of service lane should be at least 3 m (desirable).



MIN^m BED ON LEVEL GROUND	
EXPECTED MAX	
ENTRY SPEED KM/H	SUGGESTED LENGTH L (METER)
50	23
60	32
70	46
85	60
100	90
120	100

Fig. A.2.2 Layout of Arrester Bed Adjacent to Carriageway

Recovery anchors are needed to secure the tow truck when removing a vehicle from the arrester bed. A typical layout of emergency escape ramp is shown in **Fig. A.2.3**

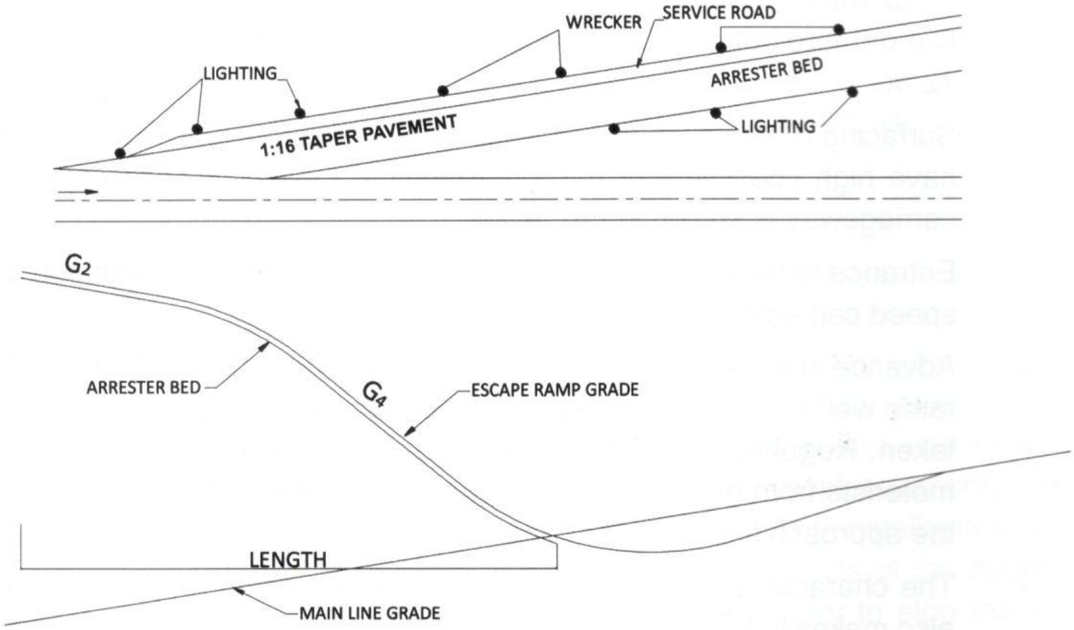
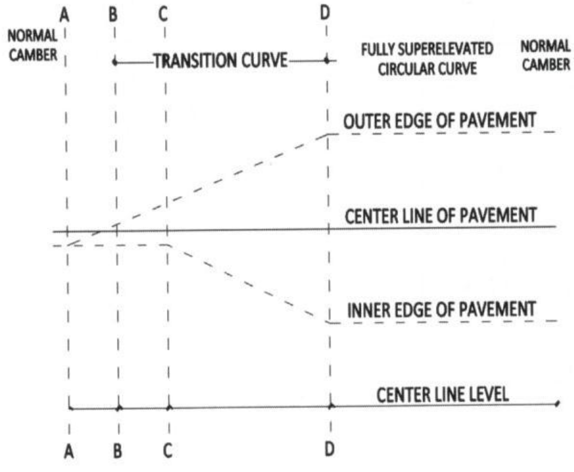
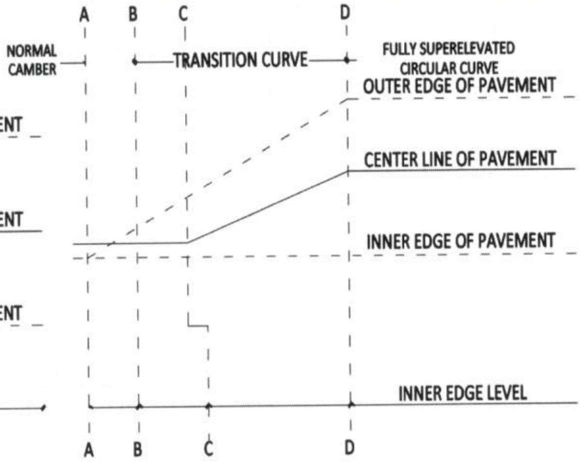


Fig. A.2.3 Layout of Emergency Escape Ramp (Left Hand Drive)

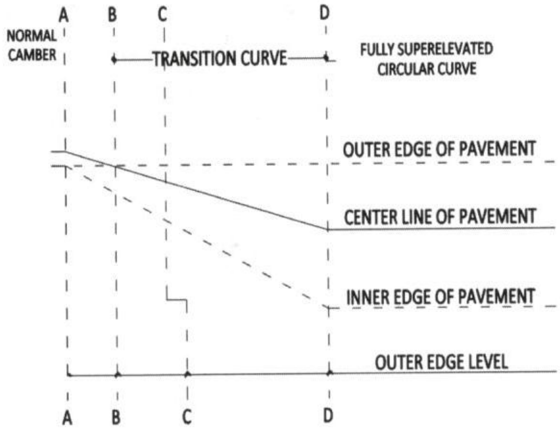
PLATE-1



(A) PAYMENT REVOLVED ABOUT CENTERLINE



(B) PAYMENT REVOLVED ABOUT INNER EDGE



(C) PAYMENT REVOLVED ABOUT OUTER EDGE

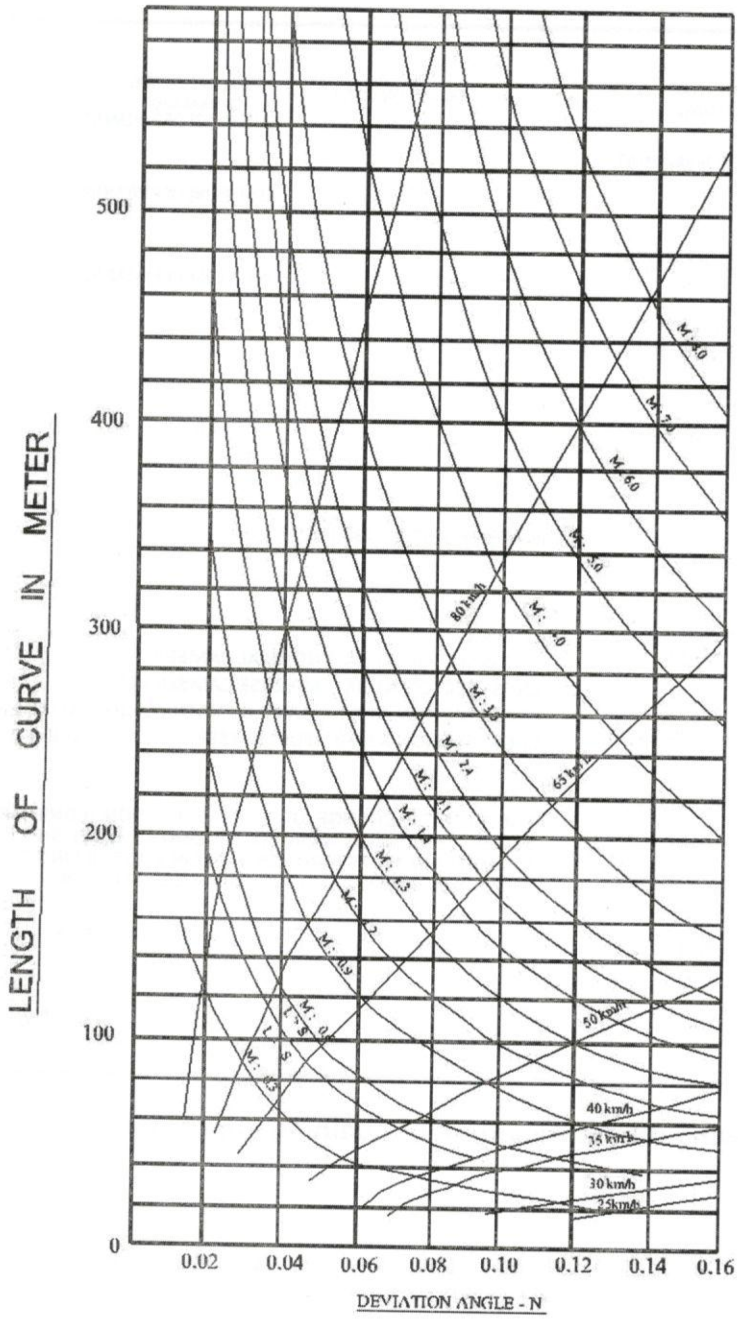
LEGEND

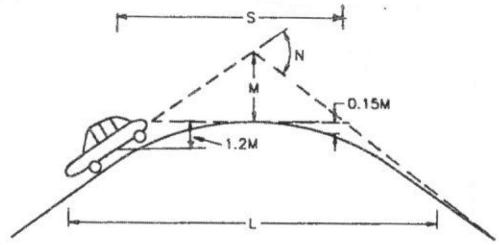
CROSS SECTON AT AA - NORMAL CAMBER
CROSS SECTON AT BB – ADVERSE CAMBER REMOVED
CROSS SECTION AT CC – SUPER ELEVATION EQUAL TO CAMBER
CROSS SECTION AT DD – FULL SUPERELEVATON ACHIEVED

NOTE:
THE RATE OF CHANGE OF SUPERELEVATION (LONGITUDINAL SLOPE OF EDGE COMPARED TO CENTRE LINE) SHOULD BE MINIMUM 1 IN 150 FOR ROADS IN PLAIN AND ROLLING TERRAIN AND 1 IN 60 IN MOUNTAINOUS AND STEEP TERRAIN.

Schematic diagrams showing different method of attaining superelevation

PLATE-2





$$L = \frac{NS^2}{4.4} \quad (L > S)$$

$$L = 2S - \frac{4.4}{N} \quad (L < S)$$

$$M = \frac{NL}{S}$$

WHERE L= LENGTH OF SUMMIT CURVE

S= STOPPING SIGHT DISTANCE

N = DEVIATION ANGLE

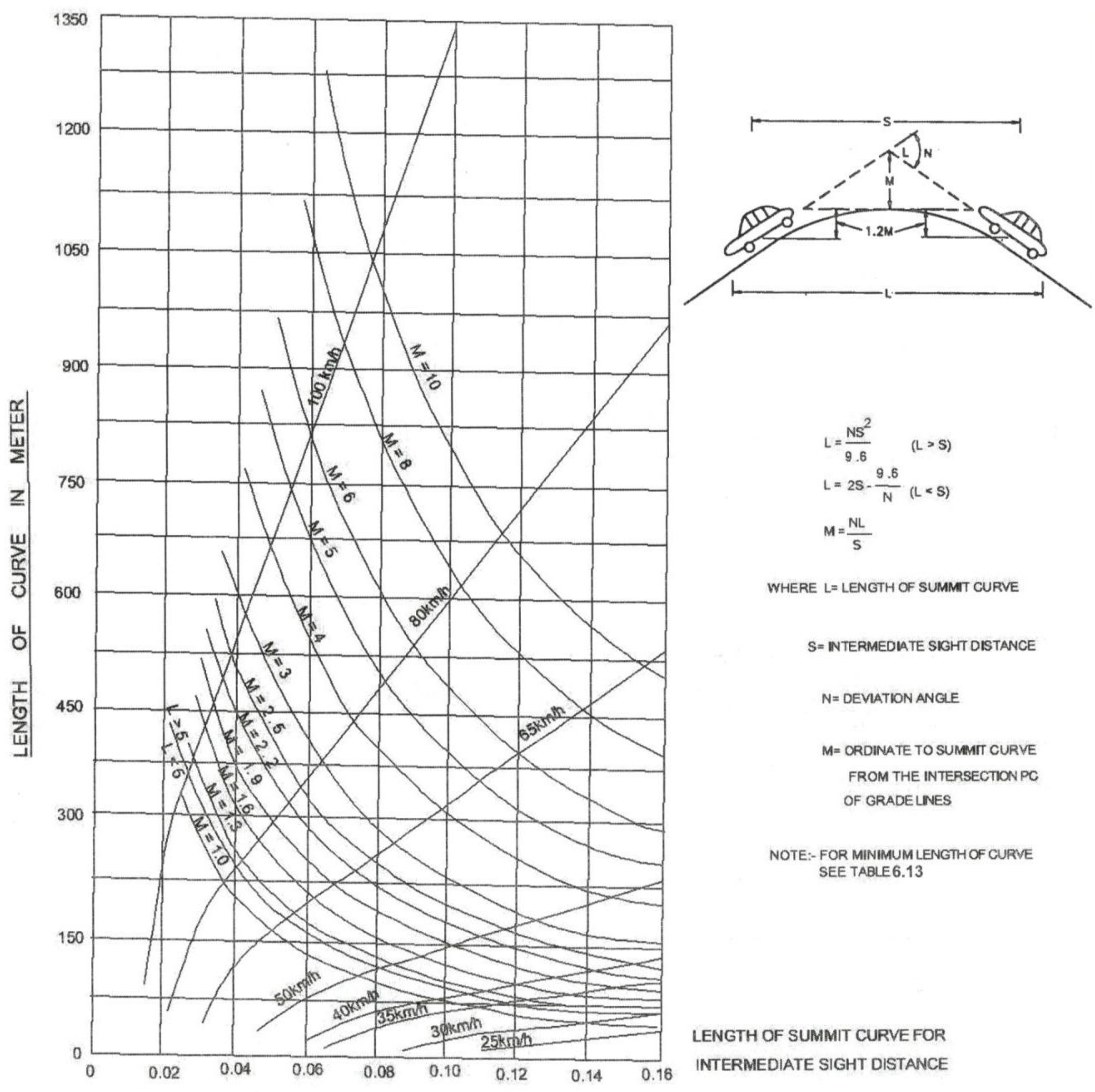
M = ORDINATE TO SUMMIT CURVE FROME THE INTER SECTION POINT OF GRADE LINES

NOTE:- FOR MINIMUM LENGTH OF CURVE SEE TABLE 6.13

LENGTH OF SUMMIT CURVE FOR STOPPING SIGHT DISTANCE

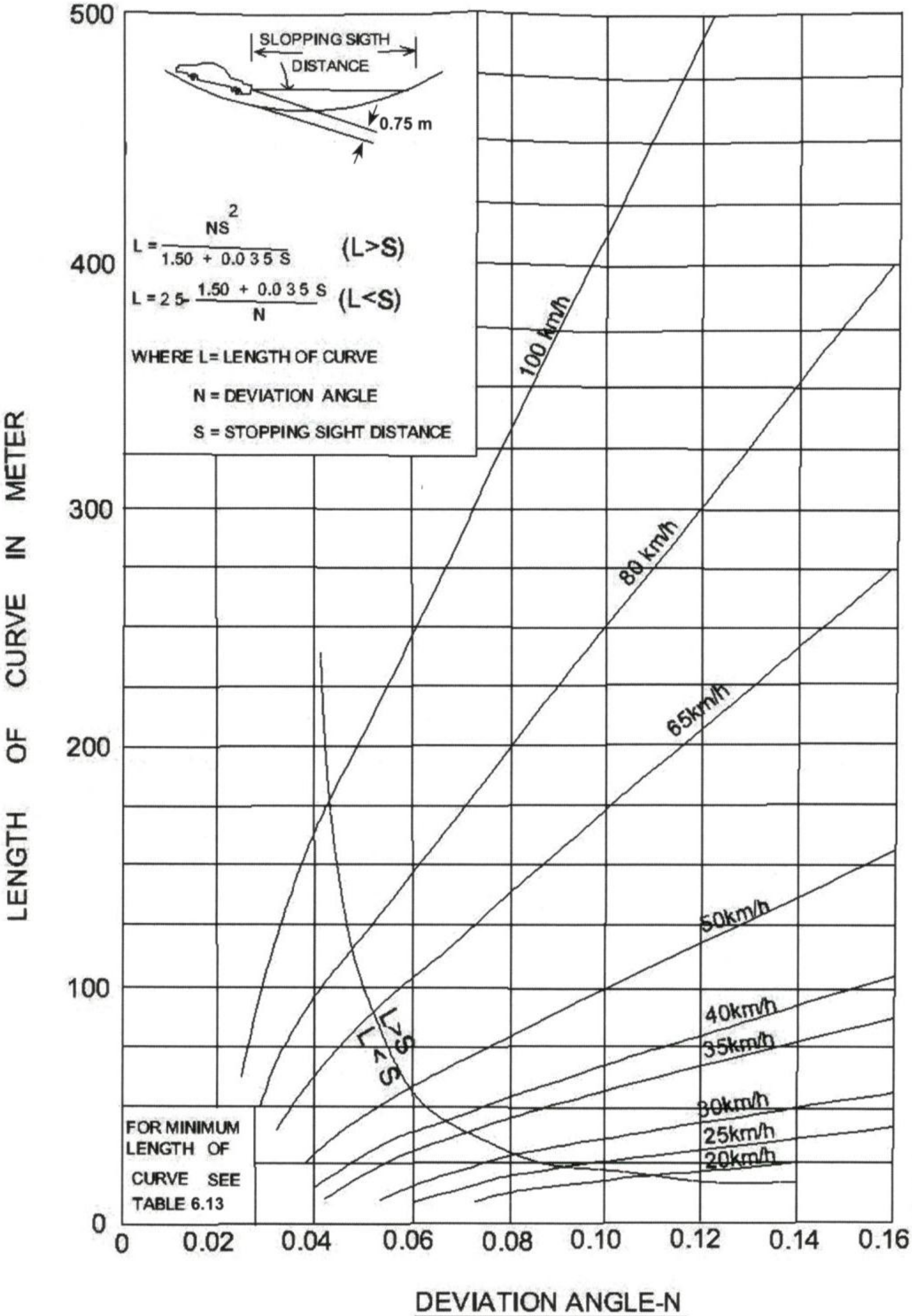
LENGTH OF SUMMIT CURVE FOR STOPPING SIGHT DISTANCE

PLATE-3



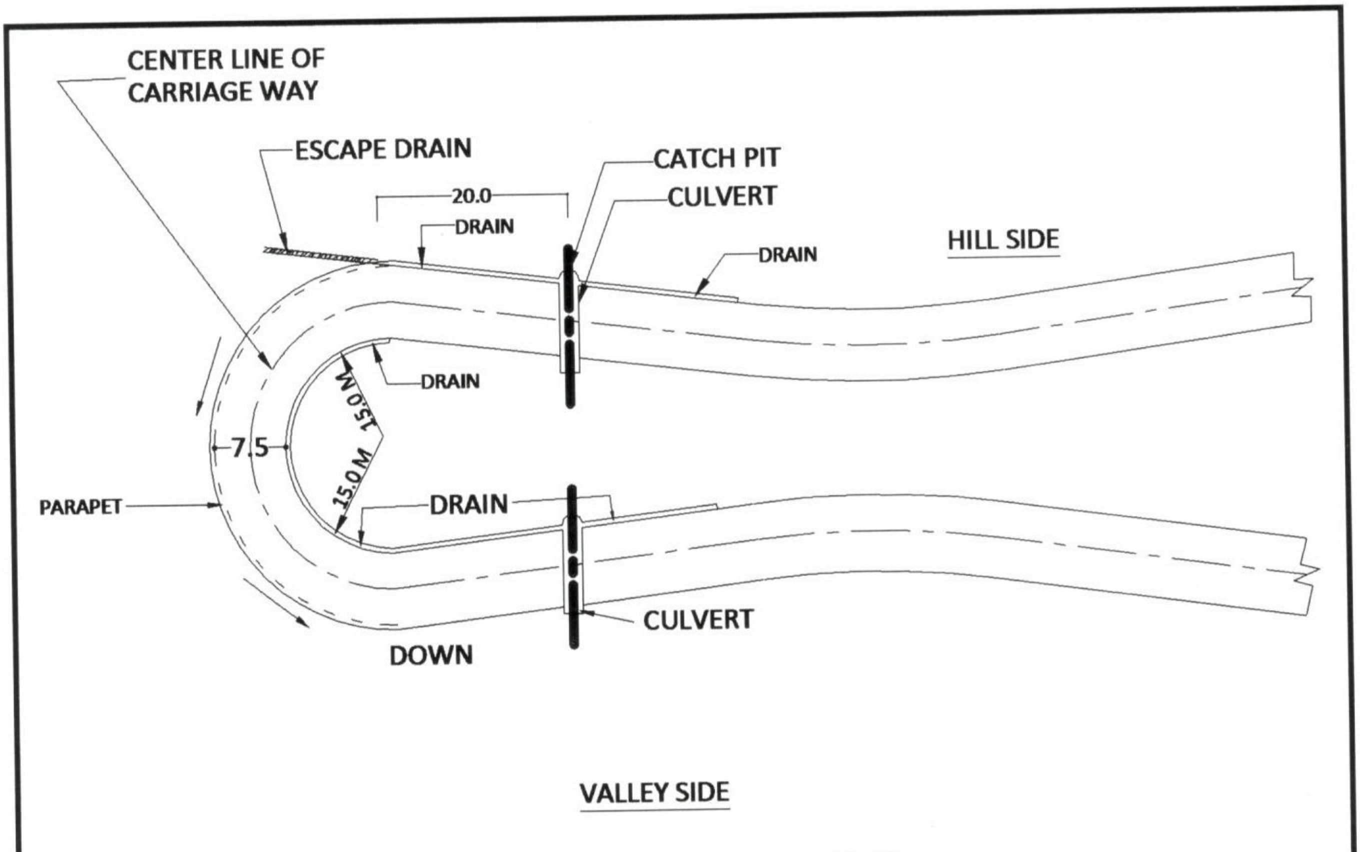
LENGTH OF SUMMIT CURVE FOR INTERMEDIATE SIGHT DISTANCE

PLATE-4



LENGTH OF VALLEY CURVES

PLATE-5



CROSS DRAINAGE IN HAIR PIN BEND

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)